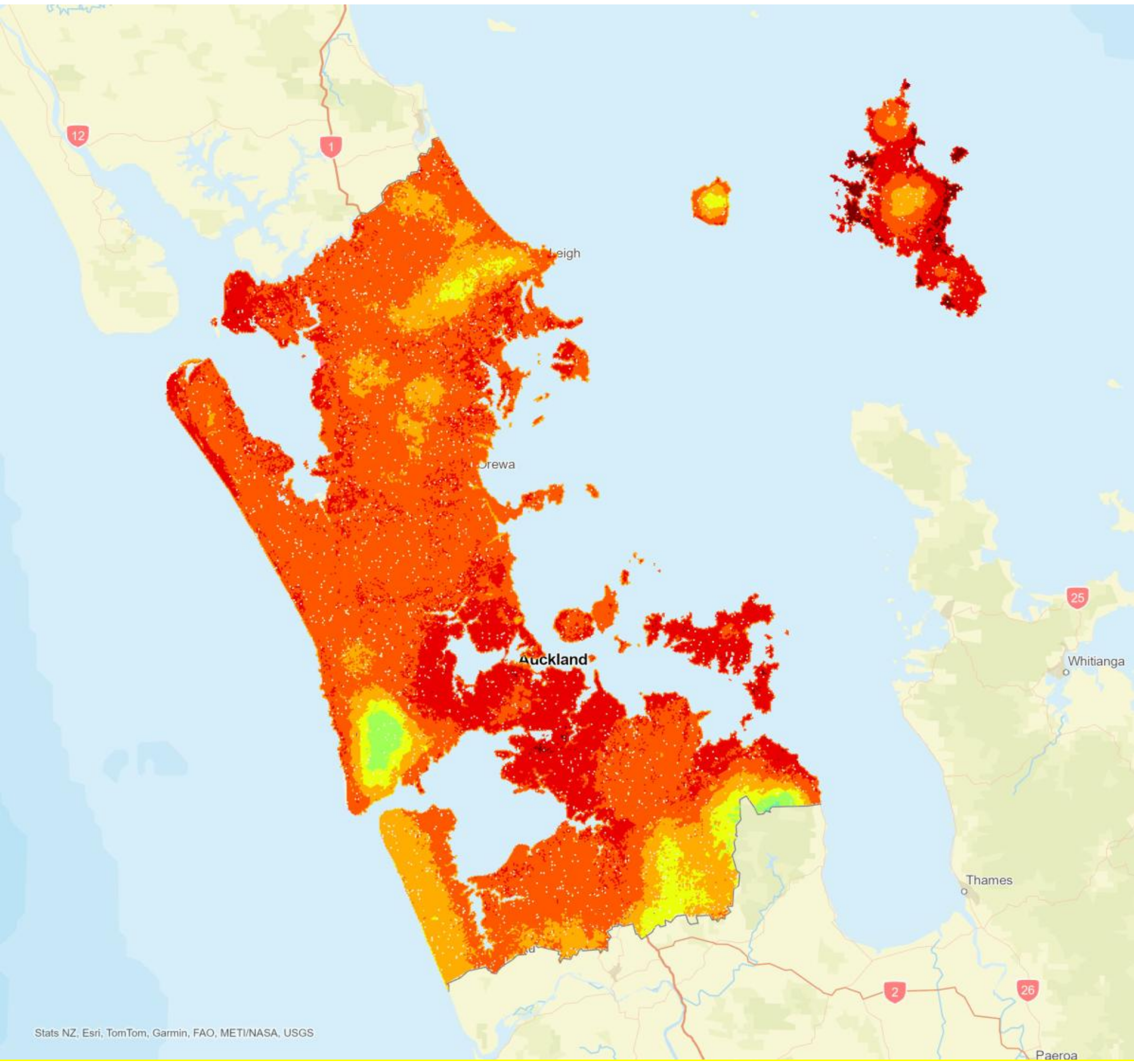
Auckland Council

Auckland Urban Heat Assessment – Future Climate

Technical Report

Reference:

Issue 02 | April 2026



Job number 312781-00

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Auckland urban heat assessment- Future climate technical report. Prepared by Arup New Zealand Limited for Auckland Council, March 2026.

ISBN 978-1-991415-66-0 (PDF)

Document Verification

Project title Auckland Urban Heat Assessment – Future Climate

Document title Auckland Urban Heat Assessment – Future Climate Technical Report

Job number 312781-00

Document ref

File reference Auckland_Future_Urban_Heat_Assessment_Technical_Report_FinalIssue

Revision	Date	Filename			
Issue 01	30/01/2026	**Description**	Report summarising the Future Climate Urban Heat Assessment for Auckland		
			Prepared by	**Checked by**	**Approved by**
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		Signature			
Issue 02	07/04/2026	**Description**	Report summarising the Future Climate Urban Heat Assessment for Auckland – Final Issue		
			Prepared by	Checked by	Approved by
		Name	Guneet Hawley Lewis Cameron	Dimple Rana	Serryn Eagleson
		Signature			

Issue Document Verification with Document ✓

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Executive Summary

Cities are becoming hotter due to both climate change and the urban heat island (UHI) effect, where temperatures in urban areas are higher than surrounding rural regions. These rising temperatures increase risks to public health, wellbeing, and critical infrastructure, meaning that understanding how heat is distributed across the city—and how it may worsen in the future—is essential.

Auckland Council commissioned Arup in 2024 to create a detailed urban heat dataset (Arup, 2024). This study builds on that work, by examining how climate projections could influence Auckland's UHI effect in the future and assessing the impacts of future extreme heat events.

Methodology

The study used the latest climate change projections for New Zealand to analyse future urban heat conditions. Two future time periods 2050 (2041 – 2060) and 2090 (2080-2099) and three emission scenarios SSP1-2.6, SSP2-4.5 and SSP3-7.0 were analysed.

Future heat maps for Auckland were produced using a method that applies climate change projections to adjust the present-day urban heat dataset. These were produced for average summer conditions and summer heat events, which were derived through examining exceedances of temperature-based thresholds.

More detailed climate analysis—such as using a combination of WRF and Arup's UHeat tool—was not undertaken for this work. Although such an approach is possible, our simplified method was considered the most practical way to provide an indication of likely future conditions. The method followed focused on temperature changes and does not consider other environmental variables or future land use changes.

Key Findings

Future climate projections show a clear and consistent increase in summer temperatures across Auckland, with warming increasing under higher emissions scenarios and toward the end of the century. By 2090, average summer temperatures in the hottest areas could reach 23°C, with maximum daily temperatures averaged over the extended summer season exceeding 27°C.

Building on the future climate analysis of average conditions, current and future heat events were analysed, including hot days, very hot days, hot nights and heatwaves during both daytime and night-time periods. Results indicate a substantial increase in the frequency and duration of heat events, particularly under higher emissions scenarios. Our analysis over Auckland shows:

- **Hot days (>25°C)** double by 2050 and increase more than fivefold by 2090 (SSP3-7.0).
- **Very hot days (>30°C)** are rare in most climate scenarios and future periods, apart from SSP3-7.0 where, by 2090, temperatures above 30°C are seen 2.8 days over an extended summer season.
- **Heatwaves** become more frequent and longer, with the longest daytime heatwave growing from ~4 days (baseline) to over 20 days by 2090 (SSP3-7.0).
- **Night-time heat events** also rise dramatically, with heatwave frequency and duration more than doubling by 2090 (SSP3-7.0).

While regional averages are presented for heat events, they are not spatially uniform. Urban areas experience higher temperatures and more frequent heat events than the Auckland average.

Conclusions

Auckland is expected to face increasing heat risk due to the combined influence of climate change and the urban heat island effect. This future climate assessment improves understanding of the temperatures likely to be experienced in urban areas, extending beyond changes in average conditions, to show how hot days and hot nights, as well as the frequency and duration of heatwaves, are projected to increase over time.

The study shows how elevated temperatures impact a wider area of the region in the future. The locations of urban heat hotspots, which represent areas where temperatures are elevated relative to their local surroundings, remain broadly consistent with the baseline. However, as future temperatures increase, the analysis enables a deeper understanding of how hot these hottest areas across Auckland can get and how priority areas identified in the baseline study will change in the future.

These findings highlight the importance of integrating heat considerations into urban design, green infrastructure, and mitigation planning, to strengthen Auckland's heat resilience and protect infrastructure and community wellbeing. The study could be further extended to include modelling population growth, land-use change, and additional climate variables such as wind and humidity, to provide a more complete picture of future urban heat risks.

1. Introduction

Cities are getting hotter. This is due to global climate change as well as the urban heat island effect, which results in higher temperatures in urban areas compared to their rural surroundings. This poses an increased risk for the health and wellbeing of people in cities, as well as putting a greater pressure on buildings and infrastructure. To address these challenges, the scale and distribution of urban heat and the impact of climate change on temperatures needs to be understood.

In 2024, Auckland Council commissioned Arup to develop a comprehensive urban heat dataset to support communication around heat-related hazards and inform climate adaptation planning. Building on this work, this study has explored how future climate projections may influence the urban heat island effect in Auckland and assess the potential impacts of extreme heat events.

1.1 Scope of assessment

The main objective of this assessment was to provide Auckland Council with a future climate urban heat dataset for the Auckland region (approximately 4,940 km^2), as analysed in the 2024 study assessing current urban heat risk.

Figure 1 shows the Auckland Council boundary. This area is referred to as the Area of Interest (AOI) for this assessment.

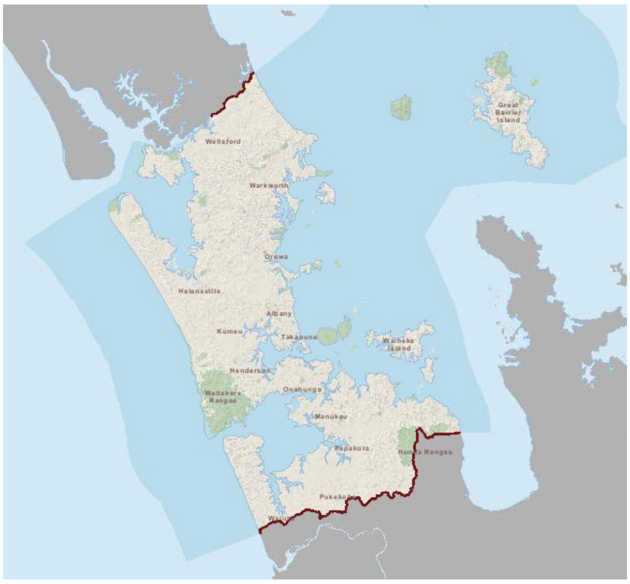


Figure 1: Auckland Council boundary. Source: https://geomapspublic.aucklandcouncil.govt.nz/viewer/index.html

Climate change projections for New Zealand were processed along with the baseline urban heat dataset results to understand the future impacts of UHI across Auckland. This was done to understand changes in the daily mean, minimum and maximum temperatures over the full summer analysis period, as well as changes in daytime and night-time heat events.

The following terminology is used is this section to represent different past datasets.

Baseline: Baseline results refer to the urban heat dataset produced by Arup in 2024. The time period analysed was November 2021 – March 2022.

Historical: Historical refers to the climate projections dataset, where a historical period was run for 1960-2014 in developing the projections. This is before different emission scenario futures are applied from 2015.

Reference: The reference period is the 20-year period used in the climate change analysis to represent the baseline urban heat dataset.

2. Methodology

2.1 Climate Change Projection Data

The latest climate projections for New Zealand were used in the study. These are based on the original ensemble of six global climate models (GCMs) which were spatially downscaled to 5km and bias-corrected for New Zealand (Gibson, et al., 2024). Such models can help consider possible future climate scenarios or outcomes, but no model that attempts to project the future can do so with certainty.

A dataset of projections clipped geospatially around Auckland was provided directly by Earth Sciences New Zealand [1]. This was a daily timeseries for mean (TAS_{mean}), maximum (TAS_{max}), and minimum (TAS_{min}) temperatures. The dataset was provided for the Auckland AOI to consider future climate change for the following modelled scenarios:

- Two future time periods: 2050 (2041 – 2060) and 2090 (2080-2099).
- Three emission scenarios: SSP1-2.6, SSP2-4.5 and SSP3-7.0.

The projections for mean summer temperature are shown in Figure 2. Plots for maximum and minimum temperatures from the climate projections are presented in Appendix A.

The historical period in the dataset is defined as pre-2015 and different emission scenarios are applied from 2015 to 2090. The plot shows the increase in temperature for the different emission scenarios are more comparable in the near future, compared to the end of the century, where SSP3-7.0 projects a much larger increase in temperature compared to the historical period. The shaded regions of each line show the model spread between the 10th and 90th percentile, where the solid line for each scenario is the 50th percentile model.

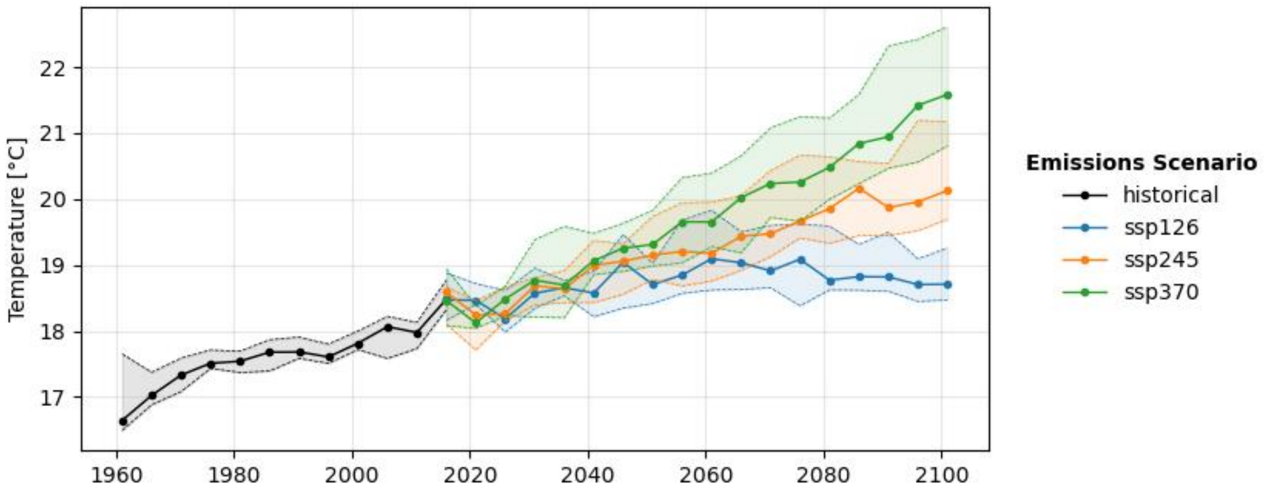


Figure 2: Climate projections for Auckland showing summer mean temperature (December-February).

[1] These are the same projections that Auckland Council have for Auckland https://www.knowledgeauckland.org.nz/publications/auckland-climate-change-cmip6-projections-for-the-auckland-region/

2.2 Overview of Method

The methodology used in this study was based on morphing, which uses monthly temperature adjustments derived from the climate projection data. These adjustments are applied to the baseline urban heat dataset (produced in 2024) to create morphed future scenarios. They represent the difference in temperature between the two periods—future and reference—as illustrated Figure 3.

The method applied in this analysis was a simplified temperature adjustment calculated from the climate projections, without re-running the UHeat model under the future climate conditions. In reality, the physics of the urban environment will change as temperatures change, as well as the impact of other climate variables not included in the study, such as wind and humidity. Furthermore, additional variables which contribute to UHI, such as increased population expected in the future, were not accounted for.

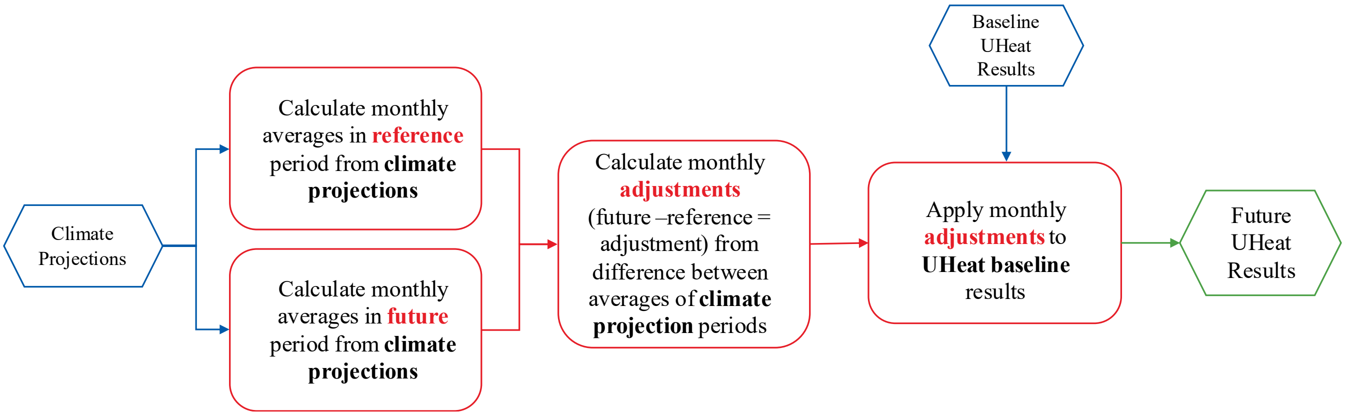


Figure 3: Climate Projections Methodology.

Monthly adjustments were calculated from the climate projections dataset, available on a 5km grid. Where this data is missing within the Auckland AOI, mostly at land-sea boundaries, the monthly adjustments were extrapolated using a nearest-neighbour approach. Monthly adjustments were downscaled to the 300m hexagons grid in the baseline urban heat dataset also using a nearest-neighbour approach. Each hexagon was assigned the value of the closest climate projection grid point. This method preserves the original adjustment values and avoids introducing additional spatial smoothing. This is shown in Figure 4.

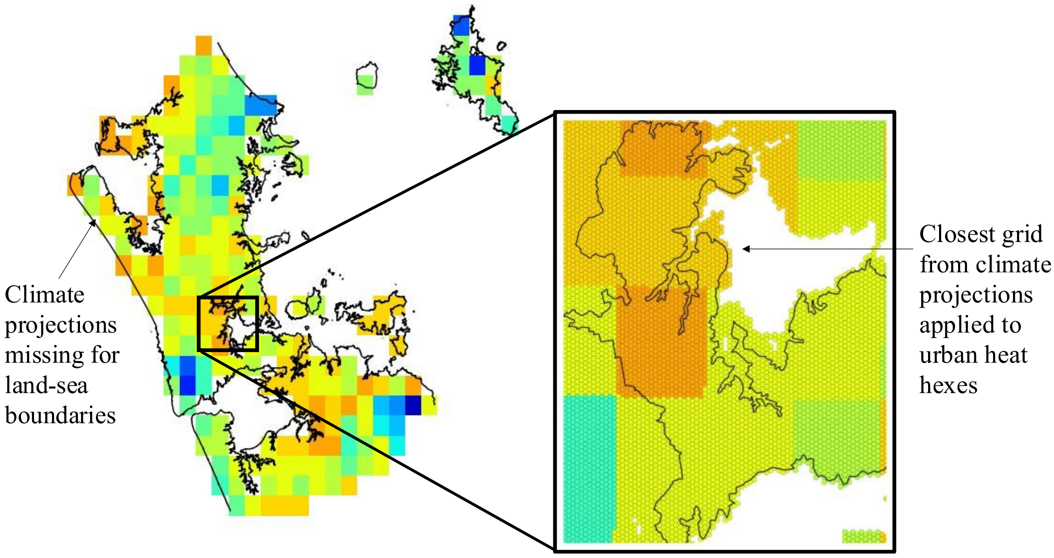


Figure 4: Methodology to apply climate projection grid data (left) to hexes used in urban heat analysis (right).

2.3 Reference Period

The baseline urban heat dataset was created through climate analysis using a combination of Weather Research Forecasting (WRF)[2] and UHeat. UHeat is an Arup tool which utilizes the Surface Urban Energy and Water Balance Scheme (SUEWS)[3] (Arup, 2024). The baseline urban heat dataset was created for one summer, November 2021 to March 2022. In contrast, climate projections are analysed over longer periods (i.e. 20 years). Therefore, a reference period for examining climate projections was required to represent the baseline urban heat dataset.

Climate data from 2003-2022 was chosen as the reference period, where the end year aligns with the baseline urban heat dataset. This reference period was used to calculate the temperature adjustments between current and future time periods. The sensitivity study carried out to select this reference period is presented in Appendix A.

2.4 Future Temperature Adjustments

The future monthly temperature adjustments averaged spatially across Auckland are presented in Figure 5. It shows the difference between the reference and future period for mean daily temperatures. This is calculated for each month individually between the two future periods 2050 (2041 – 2060) and 2090 (2080-2099) and reference period (2003-2022). Spatial plots of future temperature adjustments across Auckland are presented in Appendix A.

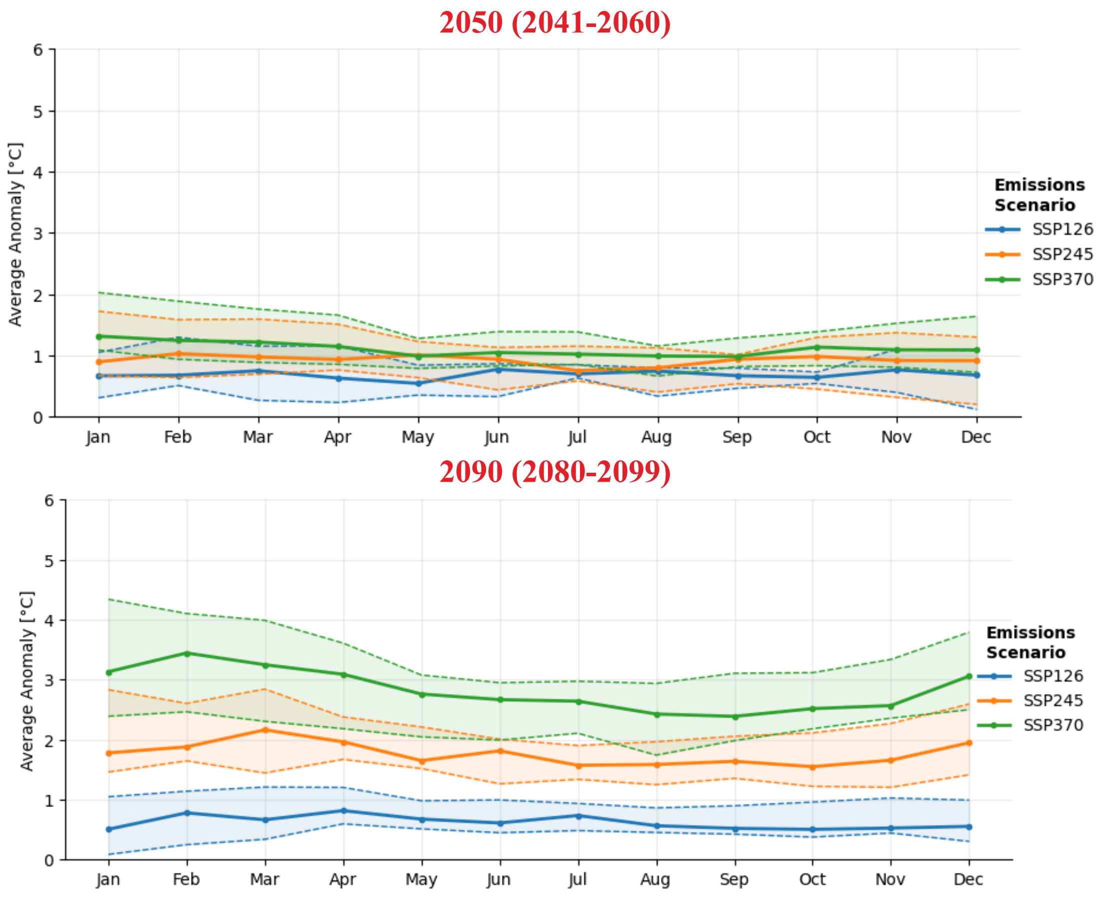


Figure 5: Mean temperature monthly uplift from the reference period (2003-2022).

[2] More information can be found at: https://www.mmm.ucar.edu/models/wrf
[3] More information can be found at: https://suews.readthedocs.io/en/latest/

Monthly temperature adjustments were also calculated for the minimum and maximum daily temperatures and are shown in Appendix A.

Since this study is only considering the extended summer period, only the monthly adjustments for November, December, January, February and March were used to morph the historical baseline urban heat dataset. The process was completed for each climate projection model individually. Results were aggregated to the 10^{th}, 50^{th} and 90^{th} percentile, to present the spread in results from processing multiple climate models

It is important to note that the baseline urban heat dataset represents only a single extended summer period (November 2021 – March 2022). In contrast, climate change projection data typically reflects an average over a much longer period, such as 20 or 30 years. Therefore, the two datasets are not directly comparable. For the purposes of this study, the future temperature adjustments were applied directly to the baseline dataset to produce the heatmaps. However, this baseline year is not necessarily typical, nor is it fully representative of the wider time periods used in climate change projections.

Using this methodology, future temperature maps were created for the three temperature variables, three emission scenarios and two future time periods, each for the 10^{th}, 50^{th} and 90^{th} percentile model spread.

2.5 Heat Events

Heat events are assessed using a set of temperature-based metrics that describe how often, how long, and how intensely high temperatures may occur. These metrics allow present-day conditions to be compared with projected future climate scenarios, to understand how climate change may affect the frequency and severity of hot weather. The analysis focuses on the southern hemisphere extended summer season (November to March), in which heat events are most likely to occur, aligning with the period of the baseline study.

2.5.1 Heat Event Metrics

Heat event metrics are calculated separately for **daytime temperatures** and **night-time temperatures**:

- **Daytime temperatures** are represented by the daily maximum temperature.
- **Night-time temperatures** are represented by the daily minimum temperature.

Together, these metrics capture both extreme daytime heat and hot nights, both of which are exacerbated by the urban heat island effect.

Variable	Metric	Definition
Maximum Temperatures	Hot Days	Number of summer days where the daily maximum temperature exceeds 25°C.
	Very Hot Days	Number of summer days where the daily maximum temperature exceeds 30°C.
	Heatwave frequency (Daytime)	Number of summer days spent in heatwave.
	Heatwave duration (Daytime)	Length of the longest summer daytime heatwave.
Minimum temperatures	Hot Nights	Number of summer days where the daily minimum temperature exceeds the calculated 90/95th percentile from the baseline reference period.
	Heatwave frequency (Night-time)	Number of summer nights spent in heatwave.
	Heatwave duration (Night-time)	Length of the longest summer night-time heatwave.

Table 1: Heat event metrics and definitions.

2.5.2 Heatwave Definitions

The **heatwave frequency** definition is aligned with that used by Earth Sciences New Zealand, which itself is based on the framework developed by Perkins and Alexander in 2013 (Perkins & Alexander, 2013). A heatwave is defined as a period of at least three consecutive days during which the daily maximum temperature exceeds the 90th percentile threshold for that location and time of year. The reference period

used to calculate the threshold was 2003 to 2022. Using a 20-year reference period reduced the impact of particularly hot or cold years when deriving the thresholds.
The threshold is calculated using a moving 15-day window centred on each calendar day in the extended summer season (November to March). This approach ensures that heatwaves are identified relative to what is considered unusually hot for the season and location, rather than using a single fixed temperature threshold across the year.

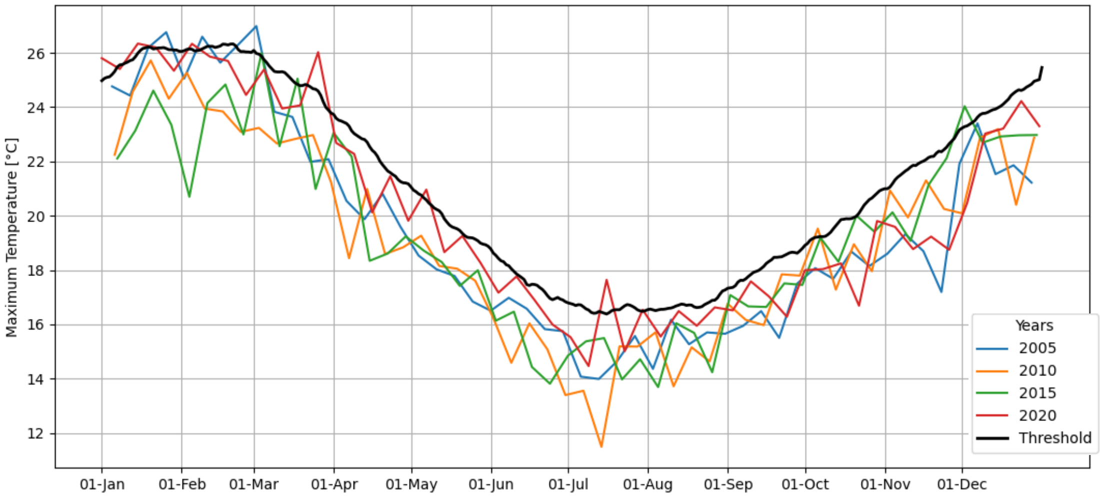


Figure 6: Daily maximum temperatures across Auckland, averaged for the reference period. The black line shows the 90th percentile temperature threshold used to identify heatwave days.

The **heatwave duration** metric calculates the largest number of consecutive days spent in a heatwave.

2.5.3 Night-time Heat Events

There is limited guidance to evaluate night-time heat events, and no established night-time heat-based threshold for Auckland. This is an important metric to consider as sustained, elevated night-time temperatures can result in adverse health impacts.

For consistency, and in the absence of existing thresholds, this study has adopted the methodology for daytime heatwaves to determine night-time heatwave frequency and duration. The method in the previous section for daytime heatwaves was followed, using daily minimum temperatures to derive night-time heatwaves, using the same 20-year reference period (2003–2022).

The hot nights metric was also calculated as an equivalent to the hot days metric, which is a single threshold of daily maximum temperatures above 25°C. To calculate hot nights, the 90th percentile of all daily minimum temperatures in the reference period was found, producing an average threshold across Auckland for hot nights of 16.8 °C.

In some international studies, heatwave metrics are defined using the 95th percentile. This study uses the 90th percentile to remain consistent with Earth Sciences New Zealand. However, the 95th percentile was also assessed for both daytime and night-time events, and the results are included in Appendix C.

3. Future Climate Results

This section presents a select subset of the climate change results. The full set of results produced in this study includes the following modelled cases:

- **Average summer conditions:** Mean Daily Temperature (TAS), Maximum Daily Temperature (TAS_{max}) and Maximum Daily Temperature (TAS_{max}).
- **Heat events:** Hot Days, Very Hot Days, Heatwave Frequency (day and night), Longest Heatwave (day and night) and Hot Nights.
- **Time periods:** 2050 (2041-2060) and 2090 (2080-2099).
- **Emission scenarios:** SSP1-2.6, SSP2-4.5 and SSP3-7.0.
- **Model percentiles:** 10^{th}, 50^{th} and 90^{th}.

3.1 Average Summer Conditions

The future urban heat distribution for mean, maximum, and minimum temperatures across the extended summer season are presented in this section. Individual days may be hotter or cooler than these averages. The results therefore represent typical summer conditions, rather than absolute temperature extremes.

Table 2 shows the maximum hotspot temperatures identified across the study area. Hotspots are areas that see elevated temperatures compared to the local surroundings. The specific hotspot temperatures presented in this section (and throughout the report) represent the maximum temperatures identified across the study area. Table 3 shows the temperature adjustments at these hotspots, which morph the baseline urban heat dataset to the future climate scenarios.

Hotspot Temperature (°C)	Baseline	2050 (2041-2060)			2090 (2080-2099)		
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP1-2.6	SSP2-4.5	SSP3-7.0
Mean Daily Temperature	19.8	20.4 (20.1-20.8)	20.7 (20.4-21.2)	21.0 (20.6-21.6)	20.4 (20.1-20.8)	21.7 (21.2-22.3)	22.9 (22.0-23.6)
Maximum Daily Temperature	23.9	24.7 (24.3-25.0)	24.8 (24.6-25.4)	25.2 (24.8-25.8)	24.6 (24.3-24.9)	25.9 (25.4-26.6)	27.2 (26.4-27.9)
Minimum Daily Temperature	18.1	18.7 (18.4-19.2)	19.1 (18.7-19.5)	19.3 (18.9-19.9)	18.7 (18.3-19.1)	20.0 (19.5-20.6)	21.1 (20.3-22.0)

Table 2: Hotspot temperatures (°C) for the climate change analysis. The 50th percentile is shown with 10th-90th in brackets.

	Baseline	2050 (2041-2060)			2090 (2080-2099)		
		SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP1-2.6	SSP2-4.5	SSP3-7.0
Mean Daily Temperature	19.8	0.6 (0.2-1.0)	0.9 (0.5-1.4)	1.2 (0.7-1.7)	0.6 (0.2-1.0)	1.8 (1.3-2.5)	3.0 (2.2-3.8)
Maximum Daily Temperature	23.9	0.7 (0.3-1.1)	0.9 (0.7-1.5)	1.3 (0.9-1.8)	0.6 (0.3-1.0)	1.9 (1.5-2.6)	3.2 (2.4-4.0)
Minimum Daily Temperature	18.1	0.6 (0.3-1.0)	0.9 (0.6-1.4)	1.2 (0.8-1.8)	0.5 (0.2-1.0)	1.8 (1.4-2.5)	3.0 (2.1-3.8)

Table 3: Hotspot temperature adjustments from baseline (°C) for the climate change analysis. The 50th percentile is shown with 10th-90th in brackets.

Across all emissions scenarios and time periods, the future temperature adjustments are similar between the mean, maximum, and minimum temperatures. The maximum temperatures show the greatest increases from the baseline, and minimum temperatures the smallest. However, the variation between temperature variables is small.

3.1.1 Heat Maps

Emissions Scenarios

Heat maps in Figure 7, showing the mean daily temperature averaged over the extended summer period, are presented for the different climate change emission scenarios for 2090 (the 50th-percentile model). These are shown alongside the equivalent baseline heat map for comparison.

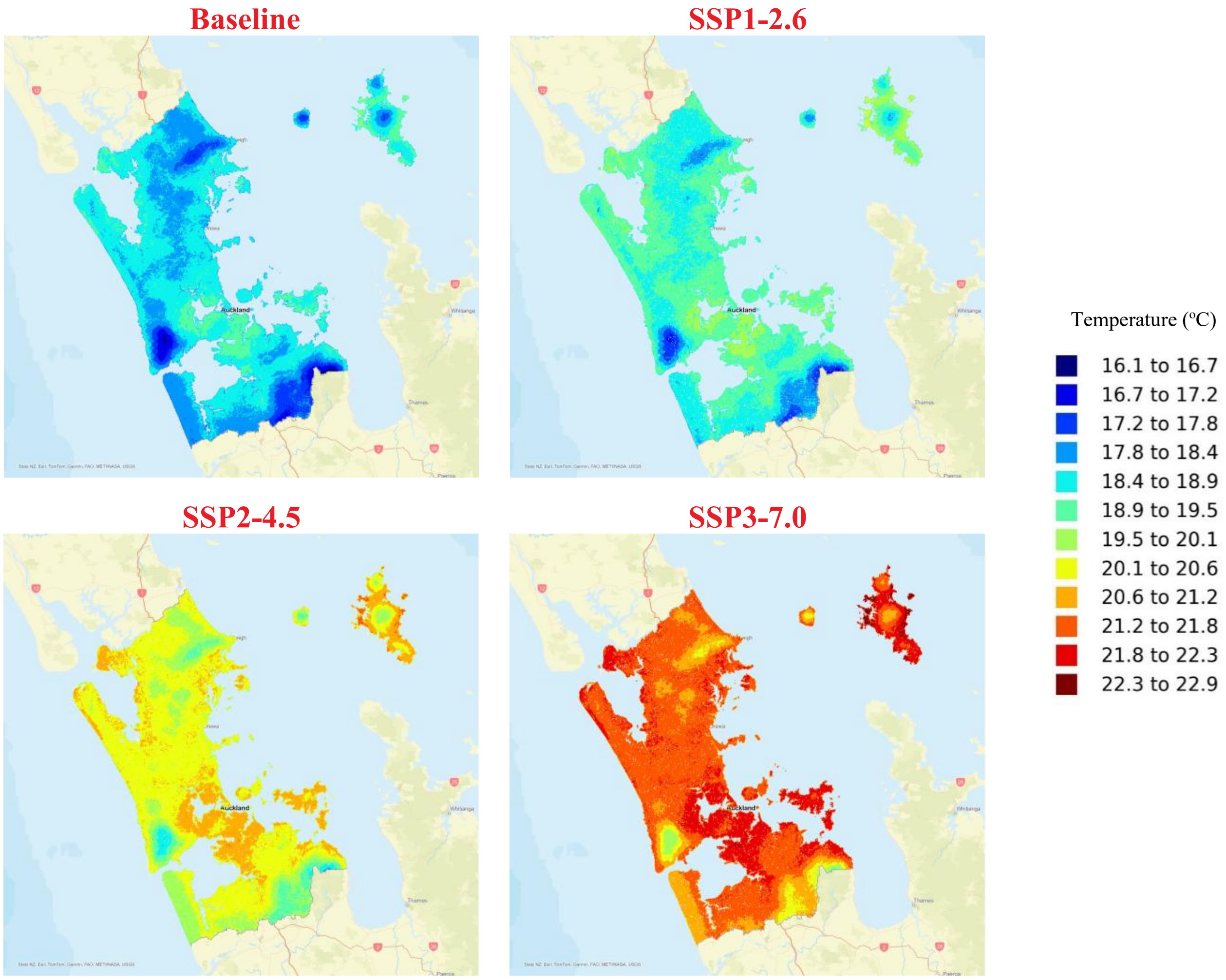


Figure 7: Summer mean daily temperature (°C) across the Auckland AOI, 2090 (2080–2099), 50th percentile model, all emissions scenarios. Baseline shown for reference. Values represent average summer conditions (November–March); individual days may be hotter or cooler.

The highest temperatures are seen for the SSP3-7.0 emission scenario, which has the highest radiative forcing and mean temperatures averaged over the summer period up to 22.9ºC at the hotspot. The SSP1-2.6 scenario shows the lowest rate of warming from the baseline, with average summer temperatures of 20.4ºC across Auckland.

In all cases the hotspots remain in the same areas, as the methodology employed entails applying temperature adjustments from the baseline temperatures

Time Periods

Heat maps in Figure 8, showing the mean daily temperature averaged over the extended summer period, are presented for the different future periods for the SSP3-7.0 emissions scenario (the 50th-percentile model). These are shown alongside the equivalent baseline heat map for comparison.

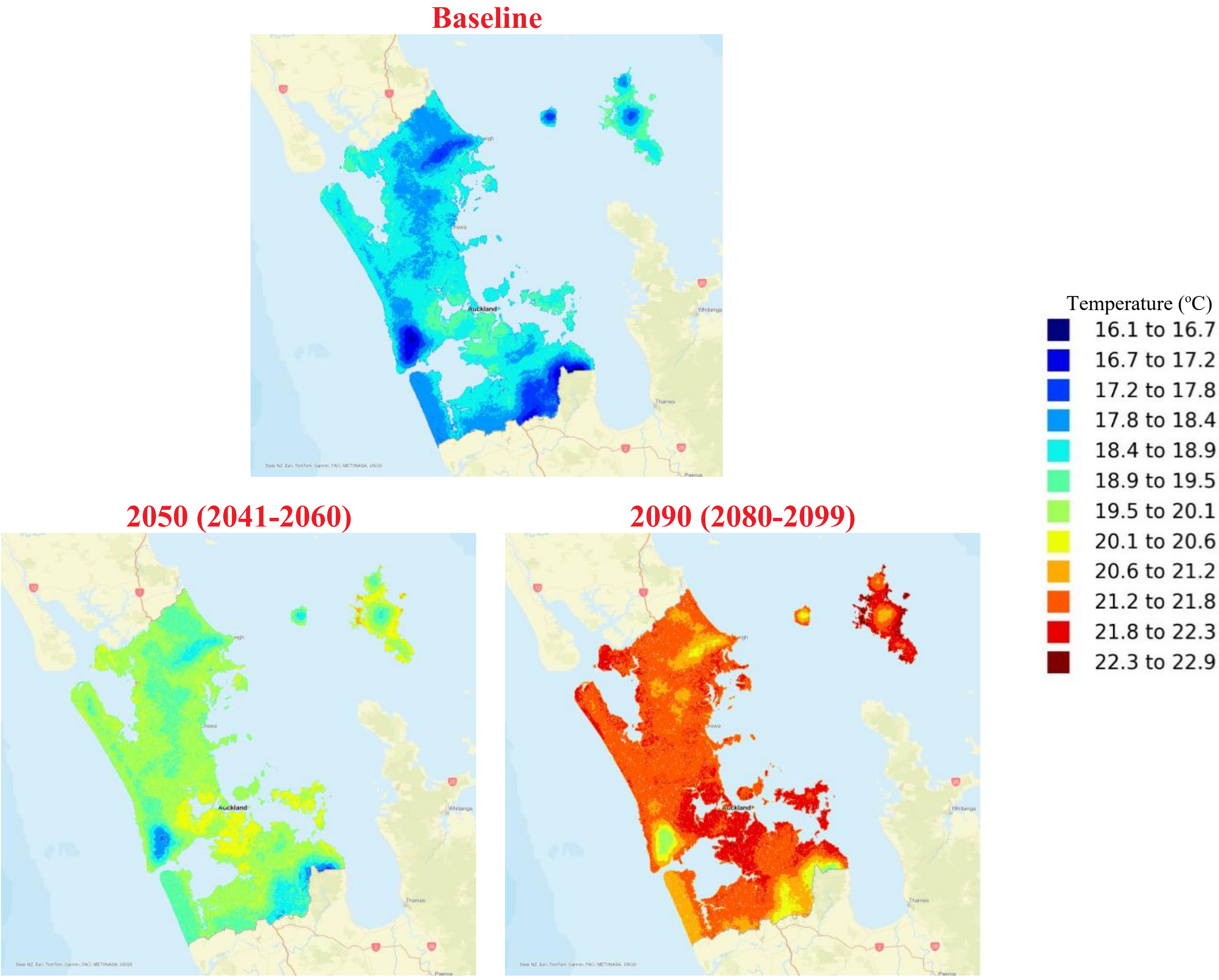


Figure 8: Summer mean daily temperature (°C) across the Auckland AOI, SSP3-7.0, 50th model percentile, all time periods. Baseline shown for reference. Values represent average summer conditions (November–March); individual days may be hotter or cooler.

The results for the different time periods for the same emission scenario and 50th model percentile show the increased warming throughout the century. The SSP3-7.0 scenario in the 2050s has the highest mean temperature over the summer period of 21.7ºC at the hotspot. This increases to 22.9ºC by 2090.

Model Percentiles

Heat maps in Figure 9, showing mean daily temperature averaged over the extended summer period, are presented for the different model percentiles for 2090 and the SSP3-7.0 emission scenario. These are shown alongside the equivalent baseline heat map for comparison.

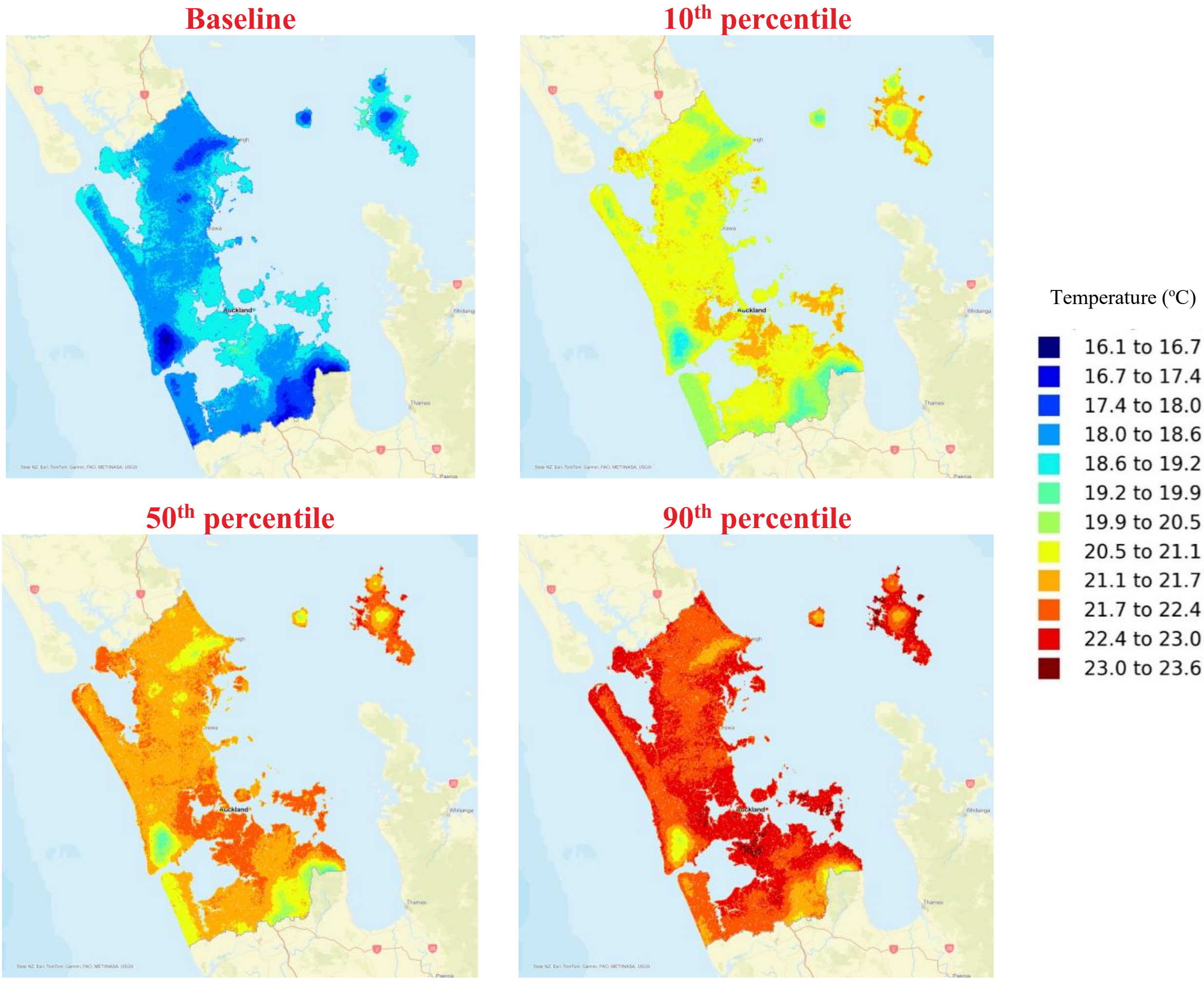


Figure 9: Summer mean daily temperature (°C) across the Auckland AOI, 2090 (2080–2099), SSP3-7.0, all model percentiles. Baseline shown for reference. Values represent average summer conditions (November–March); individual days may be hotter or cooler.

There is inherent uncertainty when considering the future climate, such as which emissions pathway society will ultimately follow in the future. This analysis has considered a range including a low emission scenario of SSP1-2.6 and high emission scenario of SSP3-7.0. There is also uncertainty in climate modelling, where multiple large-scale models are used to produce an ensemble of climate projections. As with emission uncertainty, it is important to consider the modelling uncertainty.

The spread between models and modelling uncertainty increases throughout the century, as seen earlier in Figure 5. The spatial maps in Figure 9 present a hotspot temperature for the 10th percentile model in 2090 SSP3-7.0 of 24.7ºC. The 50th percentile model gives a 22.0ºC hotspot temperature, and 23.6ºC for the 90th percentile.

Temperature Variables

Heat maps in Figure 10, show the minimum, maximum and mean temperatures averaged over the extended summer period, are presented for the SSP2-4.5 emission scenario in 2090 (50th model percentile). These are shown alongside the equivalent baseline heat map for comparison.

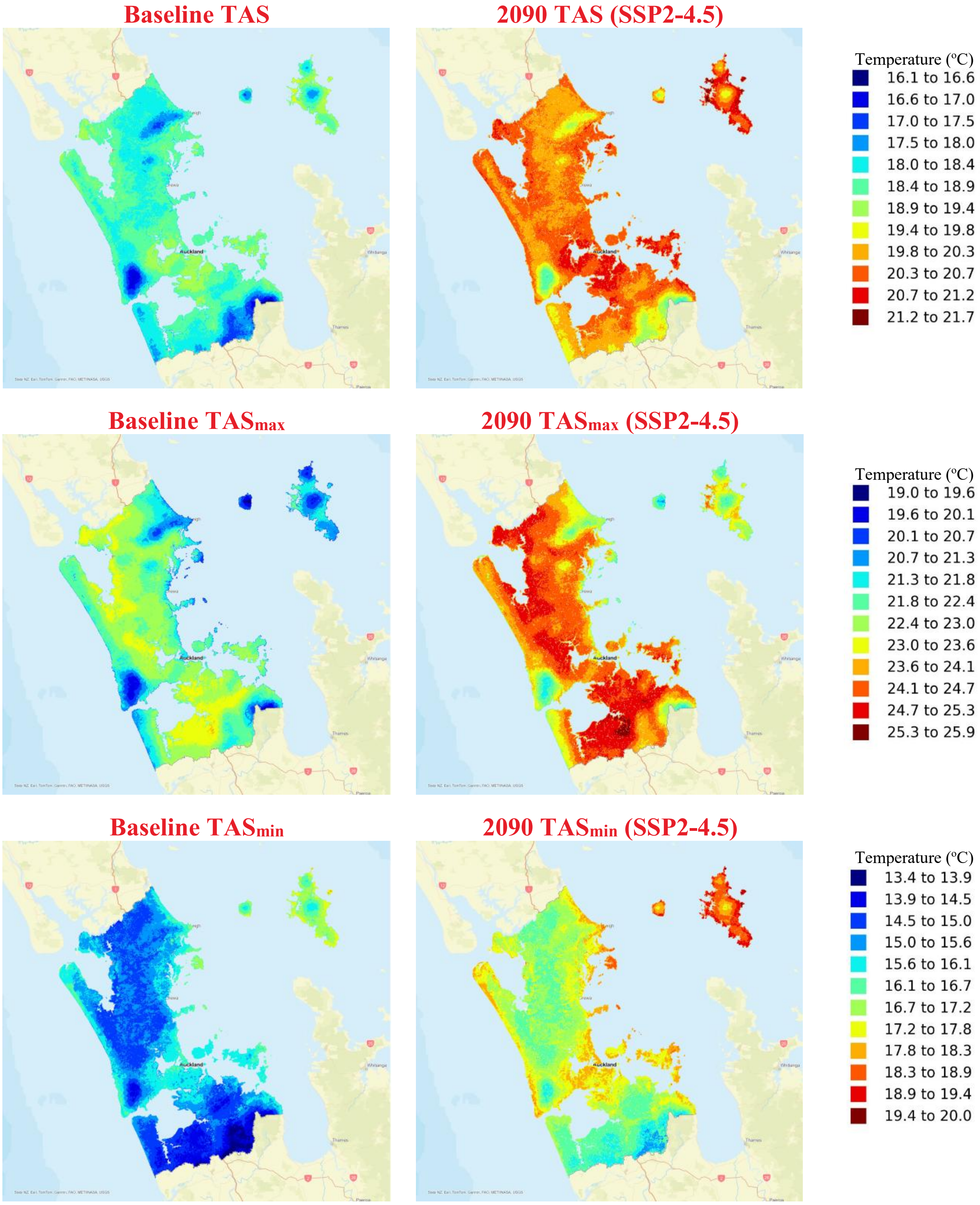


Figure 10: Summer daily mean, min and max temperature (°C) across the Auckland AOI, 2090 (2080–2099), SSP2-4.5, 50th model percentile. Baseline shown for reference. Values represent average summer conditions (November–March); individual days may be hotter or cooler.

3.2 Heat Events

This section presents the heat event metrics for Auckland AOI for the baseline and projected future climates in 2050 and 2090. The tables show all three emission scenarios analysed, whilst the plots focus on the baseline, SSP2-4.5 and SSP3-7.0. Maps for SSP1-2.6 are presented in Appendix B. Heat events are identified using a 90th percentile threshold. Results for the 95th percentile are presented in Appendix C.

The metrics are the expected average number of heat events for the extended summer season analysed in the baseline urban heat dataset, and representative future results. While regional averages are presented for heat events, they are not spatially uniform. Urban areas experience higher temperatures and more frequent heat events than the Auckland average. All heat event metrics represent the expected average number of events per summer for each period, whereas individual summers may experience higher or lower numbers of events. Table 4 summarises the heat event metrics averaged spatially across the Auckland region. Changes in these metrics from the baseline are presented in Table 5.

Threshold Indices	Baseline	2050 (2041-2060) SSP1-2.6	2050 (2041-2060) SSP2-4.5	2050 (2041-2060) SSP3-7.0	2090 (2080-2099) SSP1-2.6	2090 (2080-2099) SSP2-4.5	2090 (2080-2099) SSP3-7.0
Daytime							
Hot Days (>25°C)	16.0	27.1 (21.3 - 36.0)	31.3 (27.2 - 45.3)	39.8 (31.9 - 53.0)	25.5 (19.4 - 34.8)	55.9 (46.0 - 73.4)	87.8 (68.0 - 102.5)
V. Hot Days (>30°C)	0.0	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.1)	0.0 (0.0 - 0.2)	0.0 (0.0 - 0.0)	0.2 (0.0 - 1.6)	2.8 (0.7 - 8.6)
Heatwave Frequency	11.9	23.2 (17.1 - 31.6)	29.7 (20.7 - 41.4)	36.3 (27.6 - 51.1)	23.3 (15.4 - 29.5)	58.7 (44.5 - 78.5)	102.9 (74.7 - 120.1)
Longest Heatwave	3.7	5.9 (4.6 - 7.0)	6.7 (5.0 - 8.2)	7.5 (6.1 - 10.0)	5.7 (4.4 - 7.1)	10.7 (8.3 - 15.3)	21.1 (14.9 - 35.3)
Night-time							
Hot Nights	36.5	50.8 (44.2 - 60.7)	69.0 (47.2 - 77.8)	70.8 (58.3 - 85.8)	50.1 (38.8 - 60.6)	87.7 (74.9 - 103.5)	112.3 (96.6 - 123.9)
Heatwave Frequency	27.0	39.5 (33.2 - 48.3)	55.7 (35.7 - 65.8)	59.9 (44.5 - 74.5)	38.9 (29.8 - 48.3)	77.5 (61.5 - 97.2)	109.6 (88.8 - 127.6)
Longest Heatwave	9.3	11.8 (9.7 - 14.3)	13.6 (11.2 - 17.1)	14.8 (11.9 - 19.1)	11.5 (9.2 - 13.9)	18.3 (14.9 - 27.2)	32.9 (22.2 - 54.7)

Table 4: Heat event metrics (averaged across Auckland). The 50th percentile is shown with 10th-90th in brackets.

Threshold Indices	Baseline	2050 (2041-2060) SSP1-2.6	2050 (2041-2060) SSP2-4.5	2050 (2041-2060) SSP3-7.0	2090 (2080-2099) SSP1-2.6	2090 (2080-2099) SSP2-4.5	2090 (2080-2099) SSP3-7.0
Daytime							
Hot Days (>25°C)	16.0	+11.1 (5.3 - 20.0)	+15.3 (11.2 - 29.3)	+23.8 (15.9 - 37.0)	+9.5 (3.4 - 18.8)	+39.9 (30.0 - 57.4)	+71.8 (52.0 - 86.5)
V. Hot Days (>30°C)	0.0	+0.0 (0.0 - 0.0)	+0.0 (0.0 - 0.1)	+0.0 (0.0 - 0.2)	+0.0 (0.0 - 0.0)	+0.2 (0.0 - 1.6)	+2.8 (0.7 - 8.6)
Heatwave Frequency	11.9	+11.3 (5.2 - 19.7)	+17.8 (8.8 - 29.5)	+24.4 (15.7 - 39.2)	+11.4 (3.5 - 17.6)	+46.8 (32.6 - 66.6)	+91.0 (62.8 - 108.2)
Longest Heatwave	3.7	+2.2 (0.9 - 3.3)	+3.0 (1.3 - 4.5)	+3.8 (2.4 - 6.3)	+2.0 (0.7 - 3.4)	+7.0 (4.6 - 11.6)	+17.4 (11.2 - 31.6)
Night-time							
Hot Nights	36.5	+14.2 (7.7 - 24.2)	+32.4 (10.7 - 41.3)	+34.2 (21.8 - 49.3)	+13.6 (2.3 - 24.0)	+51.2 (38.4 - 67.0)	+75.8 (60.1 - 87.4)
Heatwave Frequency	27.0	+12.6 (6.2 - 21.3)	+28.7 (8.8 - 38.9)	+32.9 (17.5 - 47.6)	+12.0 (2.9 - 21.4)	+50.5 (34.5 - 70.3)	+82.7 (61.8 - 100.6)
Longest Heatwave	9.3	+2.5 (0.4 - 5.0)	+4.3 (1.9 - 7.7)	+5.4 (2.6 - 9.8)	+2.2 (+-0.1 - 4.6)	+8.9 (5.5 - 17.9)	+23.5 (12.8 - 45.4)

Table 5: Change in heat event metrics from the baseline (averaged across Auckland). The 50th percentile is shown with 10th-90th in brackets.

Results are for the 50th percentile of all climate models, with the 10th and 90th range shown in brackets. The model spread of heat metrics across the Auckland region is wider than the model spread for the average summer values calculated in Table 2.

3.2.1 Heat Maps

Hot Days (> 25°C)

Heat maps for hot days are shown in Figure 11. The number of hot days increases from the baseline to future periods across all emissions scenarios.

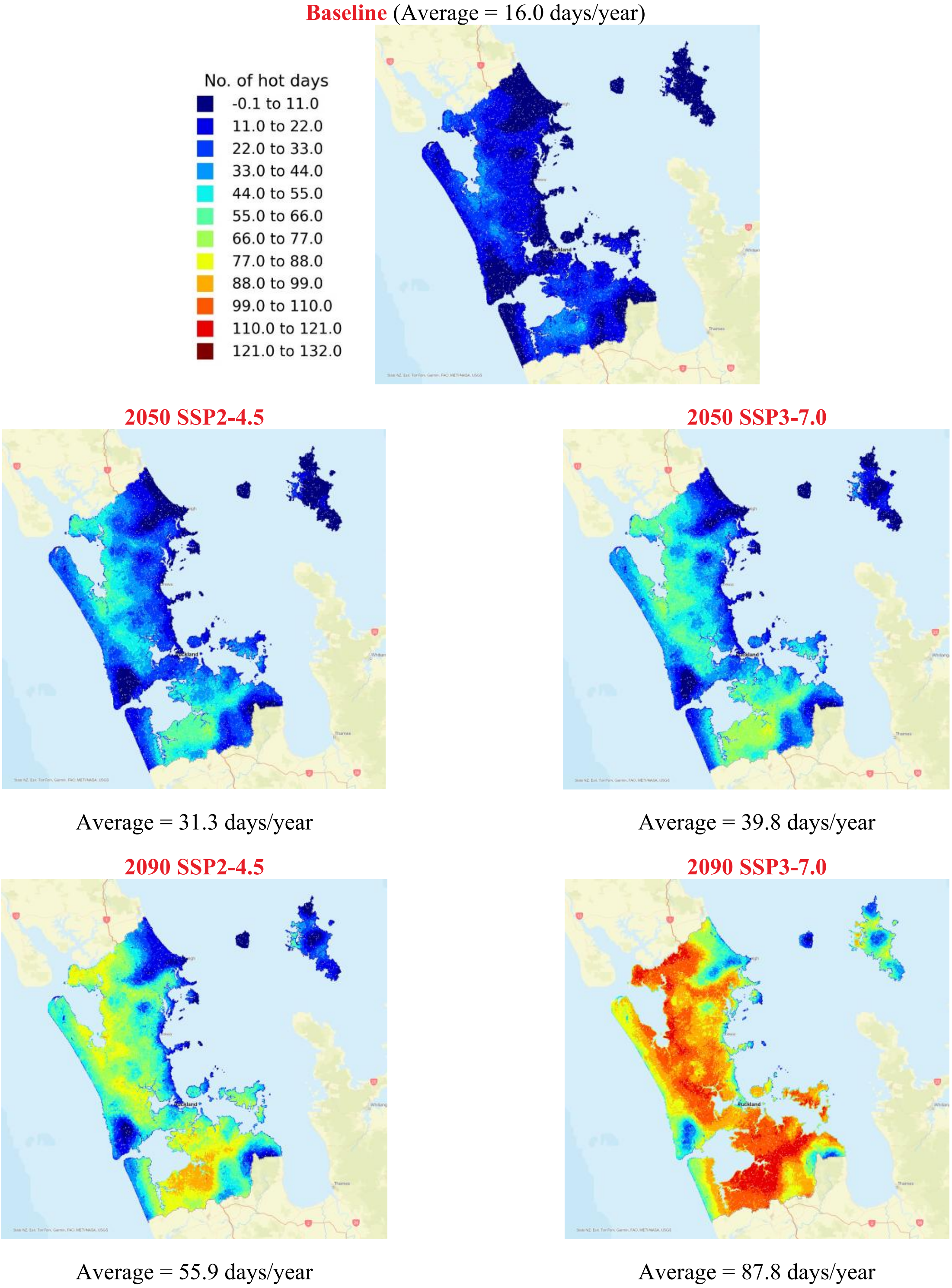


Figure 11: Hot days projected over Auckland using baseline and future urban heat analysis results (days per year).

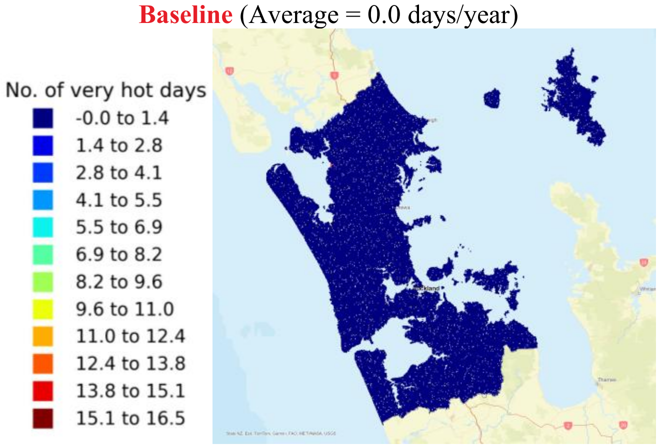
In the baseline period, Auckland experiences an average of 16 hot days per summer. By the 2050s, this increases to between 31 days (SSP2-4.5) and 40 days (SSP3-7.0). By 2090, hot days are projected to increase further, reaching 56 days under SSP2-4.5, and up to 88 days per summer under SSP3-7.0.

Although the urban areas in Auckland show a UHI effect, with elevated temperatures in the city centre, other parts of the wider Auckland region also experience higher temperatures. This is due to a range of factors. In such a large geographical area, variations in climate can arise from major atmospheric processes as well as geographical and topographical features, all of which influence local temperature patterns. This was seen in the baseline urban heat dataset (Arup, 2024), and thus is also present in the future scenarios. High maximum temperatures in these areas in the baseline were a factor of low moisture and high solar radiance in the urban heat modelling.

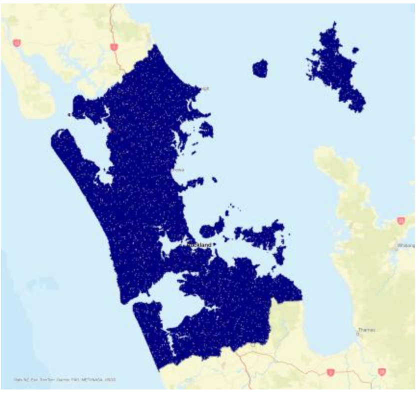
Very Hot Days (> 30°C)

Very hot days are present in some areas in the baseline period and remain rare by the 2050s across all emissions scenarios. By 2090, very hot days begin to occur more widely under higher emissions, with an average of 0.2 days in summer under SSP2-4.5 and up to 2.8 days in summer under SSP3-7.0.

Baseline (Average = 0.0 days/year)

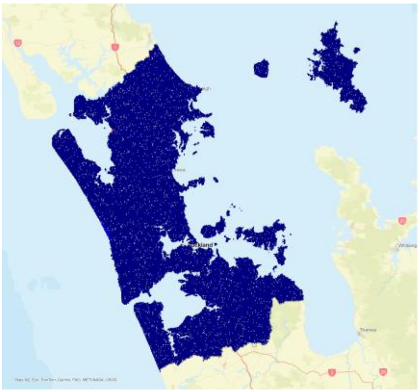


2050 SSP2-4.5



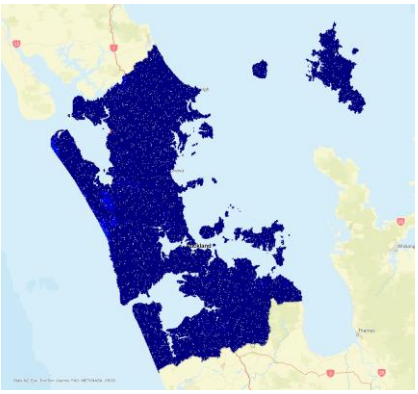
Average = 0.0 days/year

2050 SSP3-7.0



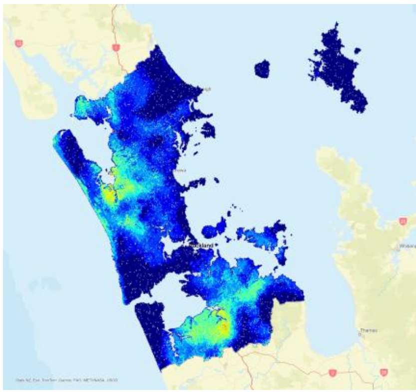
Average = 0.0 days/year

2090 SSP2-4.5



Average = 0.2 days/year

2090 SSP3-7.0



Average = 2.8 days/year

Figure 12: Very hot days projected over Auckland using baseline and future urban heat analysis results (days per year)

Heatwave Frequency (Daytime)

In the baseline, Auckland experiences an average of 12 heatwave days per summer. By the 2050s, this increases to between 30 days (SSP2-4.5) and 36 days (SSP3-7.0). By 2090, daytime heatwave days increase further to around 59 days under SSP2-4.5, and 103 days per summer under SSP3-7.0, indicating that heatwaves account for a much larger portion of the extended summer season.

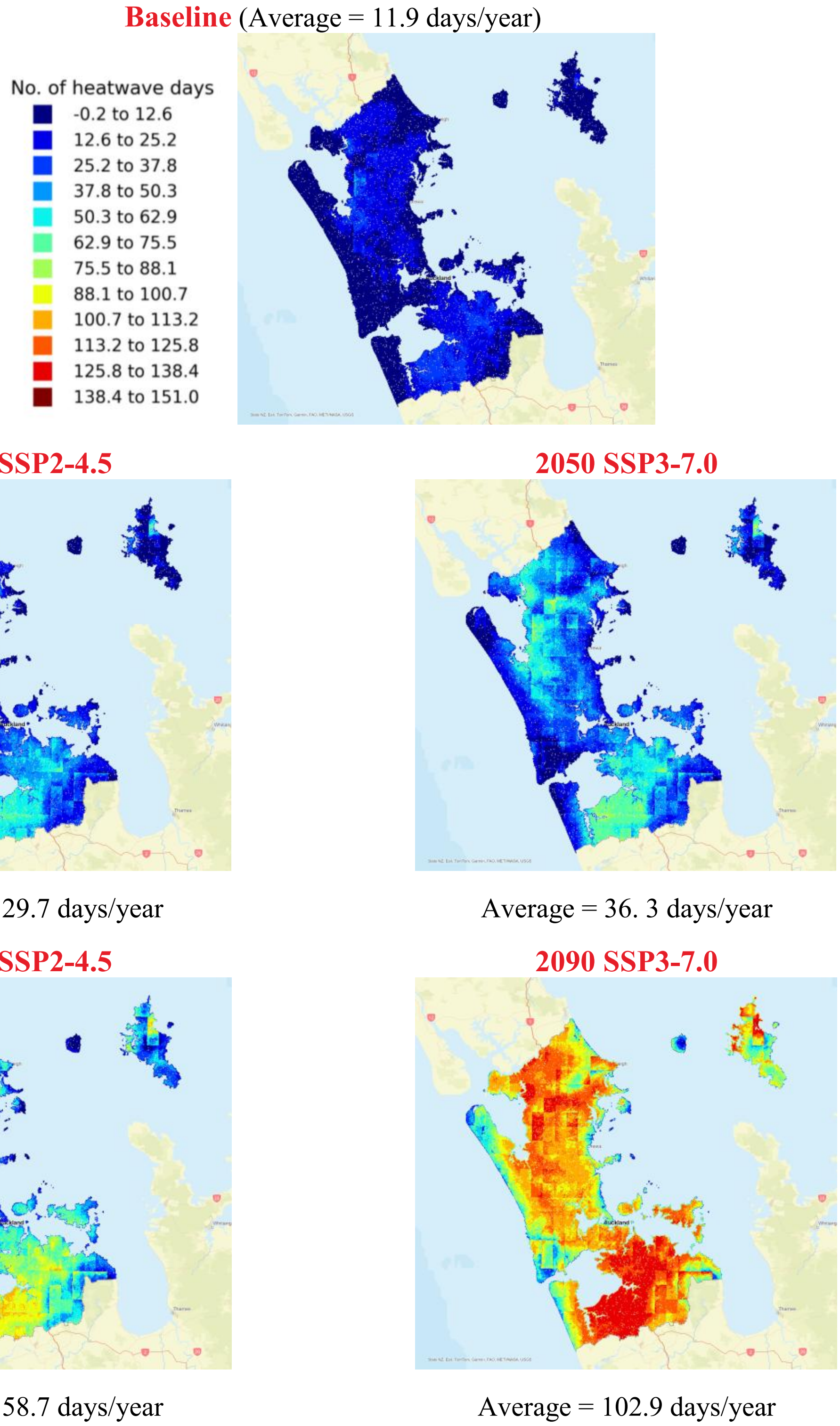


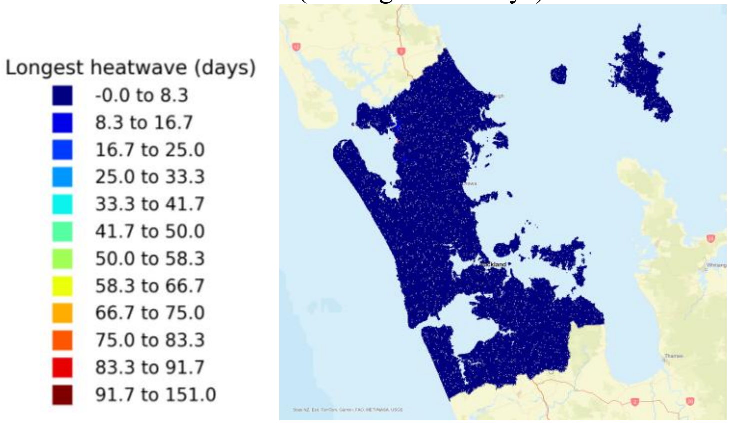
Figure 13: Daytime heatwaves projected over Auckland using baseline and future urban heat analysis results (days per year).

The checkerboarding seen in some of the heat metrics plots, such as in Figure 13, is because the heatwave percentile thresholds are calculated on the climate projections dataset, per grid square. Therefore, this effect in the maps is an artifact of the thresholds used in the analysis being on a lower resolution grid than the future urban heat results.

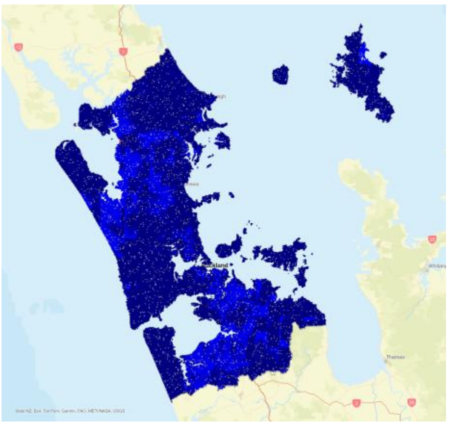
Heatwave Duration (Daytime)

In the baseline period, the longest daytime heatwave lasts on average 3.7 days. By the 2050s, this increases to between 6.7 days (SSP2-4.5) and 7.5 days (SSP3-7.0). By 2090, the longest daytime heatwave is projected to last approximately 10.7 days under SSP2-4.5, and up to 21 days under SSP3-7.0.

Baseline (Average = 3.7 days)

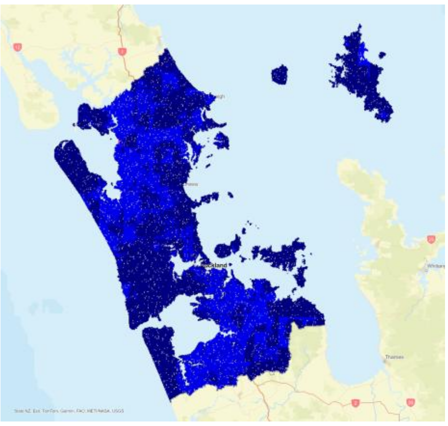


2050 SSP2-4.5



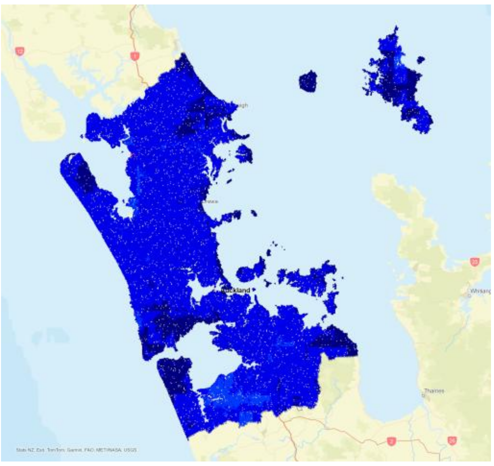
Average = 6.7 days

2050 SSP3-7.0



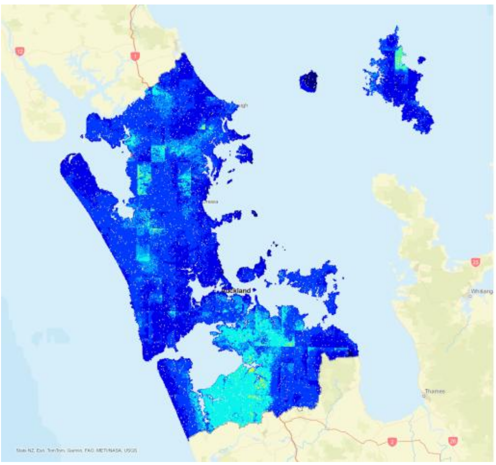
Average = 7.5 days

2090 SSP2-4.5



Average = 10.7 days

2090 SSP3-7.0



Average = 21.1 days

Figure 14: Longest daytime heatwave projected over Auckland using baseline and future urban heat analysis results (days).

Hot Nights

In the baseline urban heat dataset, Auckland experiences an average of 37 hot nights in summer. This is high for the baseline, as the urban heat analysis was conducted on a warm summer (November 2021-March 2022), whereas the threshold was defined from a longer reference period (2003-2022). By the 2050s, hot nights increase to between 69 nights (SSP2-4.5) and 71 nights (SSP3-7.0). By 2090, hot nights rise further to approximately 88 nights under SSP2-4.5, and over 112 nights per summer under SSP3-7.0.

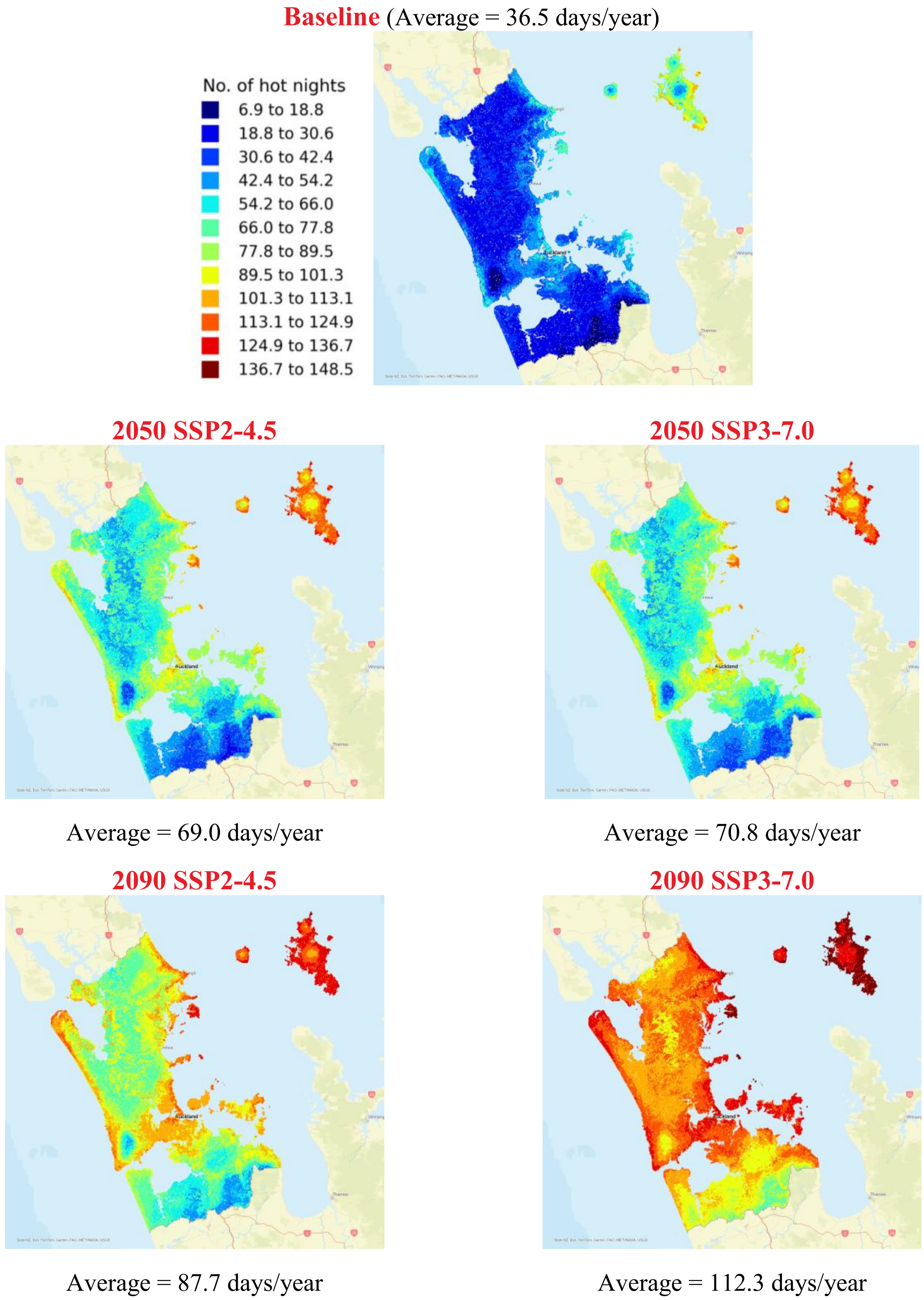


Figure 15: Hot nights projected over Auckland using baseline and future urban heat analysis results (days per year).

Rural areas which showed high daytime maximum temperatures, show lower night-time minimum temperatures. The urban areas such as Auckland city centre show the greatest risk to night-time heat.

Heatwave Frequency (Night-time)

During the baseline period, Auckland experiences an average of 27 night-time heatwave days per summer. By the 2050s, this increases to between 56 days (SSP2-4.5) and 60 days (SSP3-7.0). By 2090, night-time heatwave frequency increases further to 78 days under SSP2-4.5, and up to 110 days per summer under SSP3-7.0.

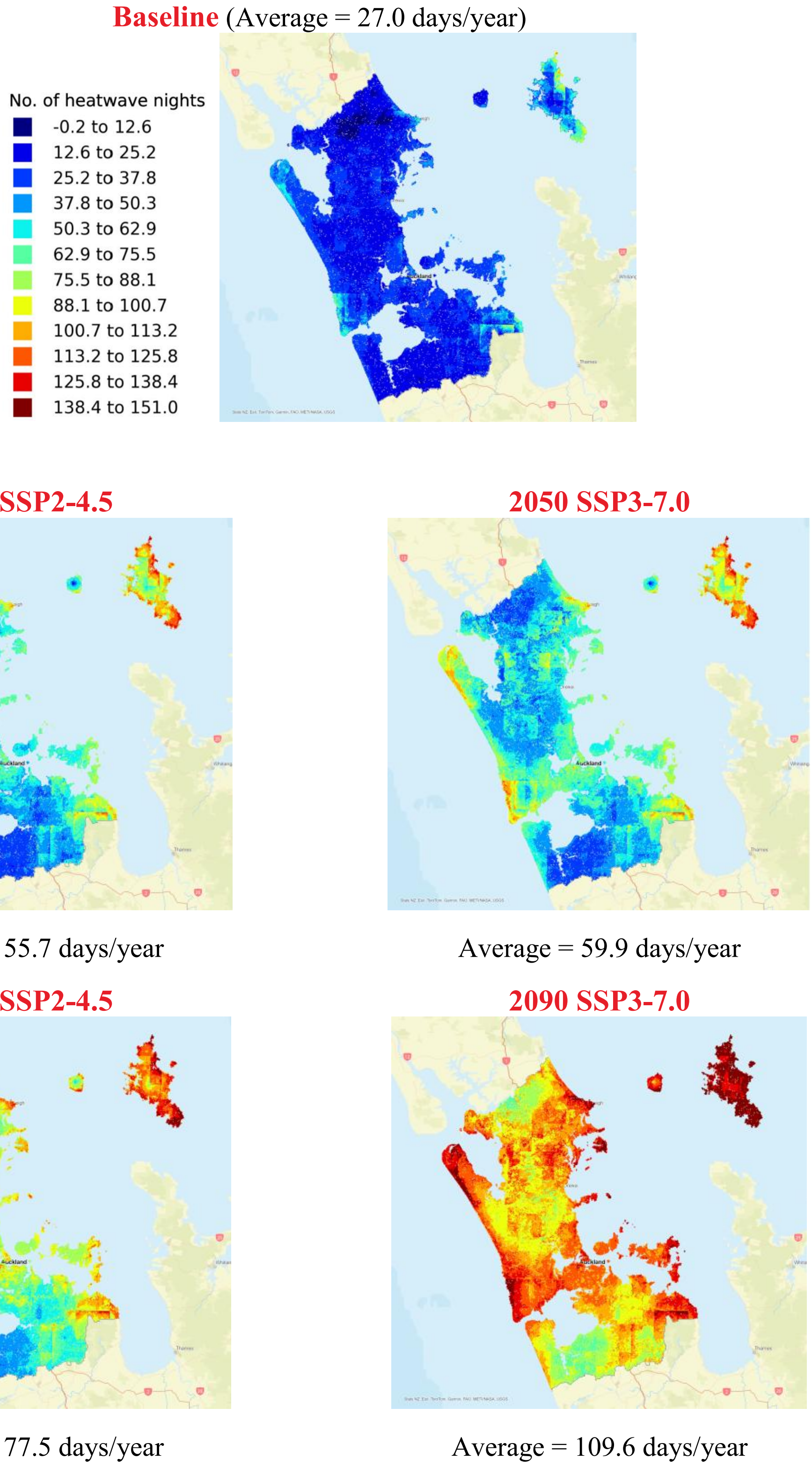
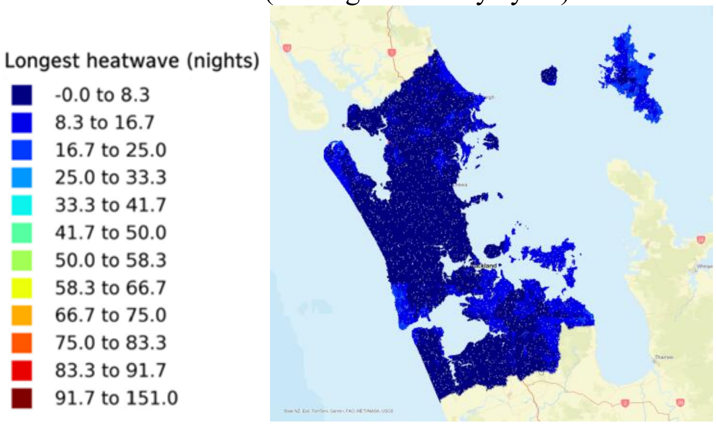


Figure 16: Night-time heatwaves projected over Auckland using baseline and future urban heat analysis results (days per year).

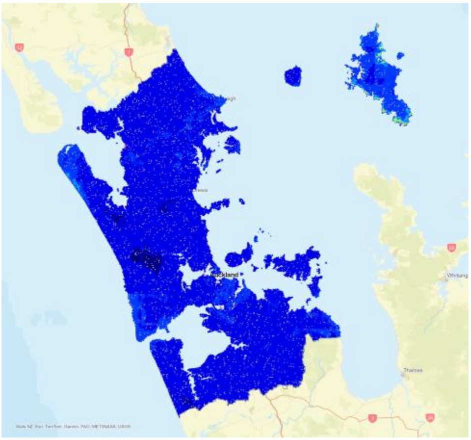
Heatwave Duration (Night-time)

In the baseline period, the longest night-time heatwave lasts an average of 9 nights. By the 2050s, this increases to between 14 nights (SSP2-4.5) and 15 nights (SSP3-7.0). By 2090, the longest night-time heatwave is projected to last approximately 18 nights under SSP2-4.5, and up to 33 nights under SSP3-7.0.

Baseline (Average = 9.3 days/year)

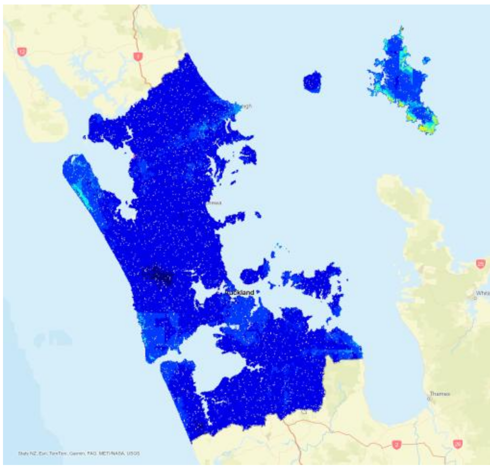


2050 SSP2-4.5



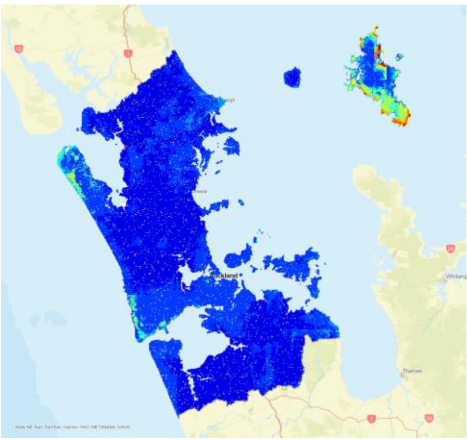
Average = 13.6 days/year

2050 SSP3-7.0



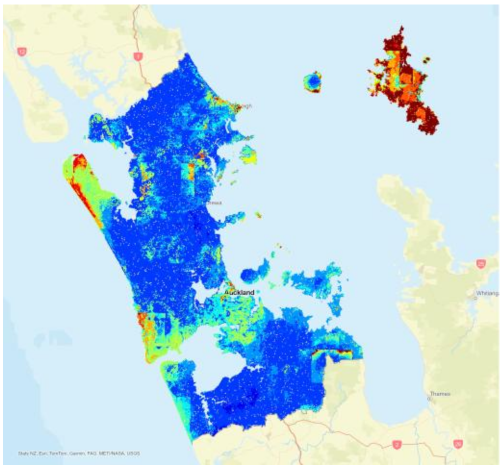
Average = 14.8 days/year

2090 SSP2-4.5



Average = 18.3 days/year

2090 SSP3-7.0



Average = 32.9 days/year

Figure 17: Longest night-time heatwave projected over Auckland using baseline and future urban heat analysis results (days).

Higher exceedances of heatwaves are seen in areas like the Great Barrier Island, partially due to large scale climate variations present in the modelling of the baseline urban heat dataset (Arup, 2024).

4. Conclusions

This assessment has examined how Auckland's urban heat patterns are expected to evolve under future climate conditions by combining baseline urban heat results with the latest climate change projections for New Zealand. In addition to analysing changes in average summer temperatures, the study has incorporated a comprehensive set of heat-event and heat-threshold metrics—including hot days, very hot days, hot nights, and both daytime and night-time heatwaves—to evaluate how the frequency and duration of extreme heat are likely to change across the region. Together, these analyses provide a detailed understanding of how both typical summer conditions and extreme heat events may intensify in a warming climate, with important implications for public health, urban resilience, and long-term planning across Auckland.

4.1.1 Summary of key findings

Average Summer Conditions

The analysis for climate projections on the UHI results for Auckland shows that warmer minimum, mean and maximum temperatures are expected in the future. This will further exacerbate the UHI at the hottest areas from the baseline urban heat dataset. The results show increased warming throughout the century, with highest temperatures for the SSP3-7.0 emission scenario. By 2090, average summer temperatures in the hottest areas could reach 23°C, with maximum daily temperatures averaged over the extended summer season exceeding 27°C.

Heat Events

The heat event metrics show an increase in the frequency and duration of heat events in Auckland under future climate conditions. Compared to the baseline period, both daytime and night-time heat events become more common, more intense, and longer-lasting, with the greatest increases occurring later in the century and under the highest emissions scenario, SSP3-7.0.

- ***Daytime heat events*** increase markedly across all scenarios. The number of hot days (>25°C) approximately doubles by 2050 and increases more than fivefold by 2090 under emissions scenario SSP3-7.0. While very hot days (>30°C) remain rare in the baseline and 2050 projections, they begin to emerge by 2090 under higher emissions, indicating the increasing likelihood of more extreme daytime temperatures. Heatwaves also become more frequent and longer in duration, with the longest daytime heatwave increasing from around 4 days in the baseline to over 20 days by 2090 under high emissions.
- Areas outside the city centre show the greatest number of daytime heat events in summer, with the highest maximum temperatures.
- ***Night-time heat events*** show even stronger increases than daytime heat. The number of hot nights rises substantially in all future periods, more than doubling by 2090 under higher emissions scenarios. Night-time heatwave frequency and duration also increase significantly, with the longest night-time heatwave extending from around 9 days in the baseline to over 30 days by 2090 under higher emissions.
- Urban areas such as city centre show the greatest number of night-time heat events in summer, with the highest minimum temperatures. These areas are at greatest risk of adverse health impacts.

4.1.2 Limitations

A simplified method was applied in this study which uses temperature adjustments across Auckland with the latest climate projections for New Zealand. Other climate variables or socioeconomic factors such as population changes were not included in the analysis.

The study is based on climate model outputs obtained from external sources including the latest local climate projections across New Zealand. Such models can help consider possible future climate scenarios or outcomes, but no model that attempts to project the future can do so with certainty. Actual events may not occur as projected.

4.1.3 Next Steps and Recommendations

The combination of UHI and climate change poses a challenge to Auckland, which requires proactive planning and adaptation measures. The insight from this assessment provides a foundation for identifying priority areas and informing strategies to reduce future heat exposure. By integrating these findings into urban design, green infrastructure planning, and emergency preparedness, Auckland can enhance its resilience and safeguard infrastructure and community wellbeing in a warming climate.

The study could be further extended with advanced analysis to incorporate additional factors not considered in this methodology. Projected population growth, land use changes, and other climate variables such as wind and humidity could be incorporated to refine the understanding of future urban heat risks.

While heat mapping provides essential insight into the hazard—showing where temperatures are highest now and how they may change in the future—understanding risk requires also considering vulnerability and exposure. A comprehensive heat-risk picture emerges only when these additional dimensions are overlaid with the hazard layers. These may include:

- Vulnerability of people, assets and systems, such as demographic characteristics (age, income, health), building type and condition, or critical infrastructure sensitivity.
- Exposure, including where people live, work and travel—such as residential areas, workplaces, schools, transport networks and key activity hubs.

We therefore recommend that Auckland Council undertakes a holistic, forward-looking and solutions-focused heat-risk assessment. Such an approach would:

- Integrate heat hazard data with vulnerability and exposure layers to reveal the communities, assets and places most at risk.
- Consider interdependencies with other climate hazards—for example, compounding effects where heat overlaps with drought, air-quality issues or power-system stress.
- Support a structured process to shortlist and prioritise adaptation measures, ensuring that interventions deliver the greatest benefit and address both current and future risk.

This integrated risk-based approach will help Auckland plan more effectively, protect vulnerable communities, and build long-term resilience as temperatures continue to rise.

5. References

Arup. (2024). *Auckland Urban Heat Assessment: Technical Report.* Auckland.

Gibson, P. B., Stuart, S., Sood, A., Stone, D., Rampal, N., Lewis, H., . . . Morgenstern, O. (2024). Dynamical downscaling CMIP6 models over New Zealand: added value of climatology and extremes. *Climate Dynamics* , 8255–8281.

Perkins, S. E., & Alexander, L. V. (2013). On the Measurement of Heat Waves. *Journal of Climate*, 4500-4517.

A.1 Appendix A – Climate Change Methodology

A.1.1 Climate Change Projections for Auckland

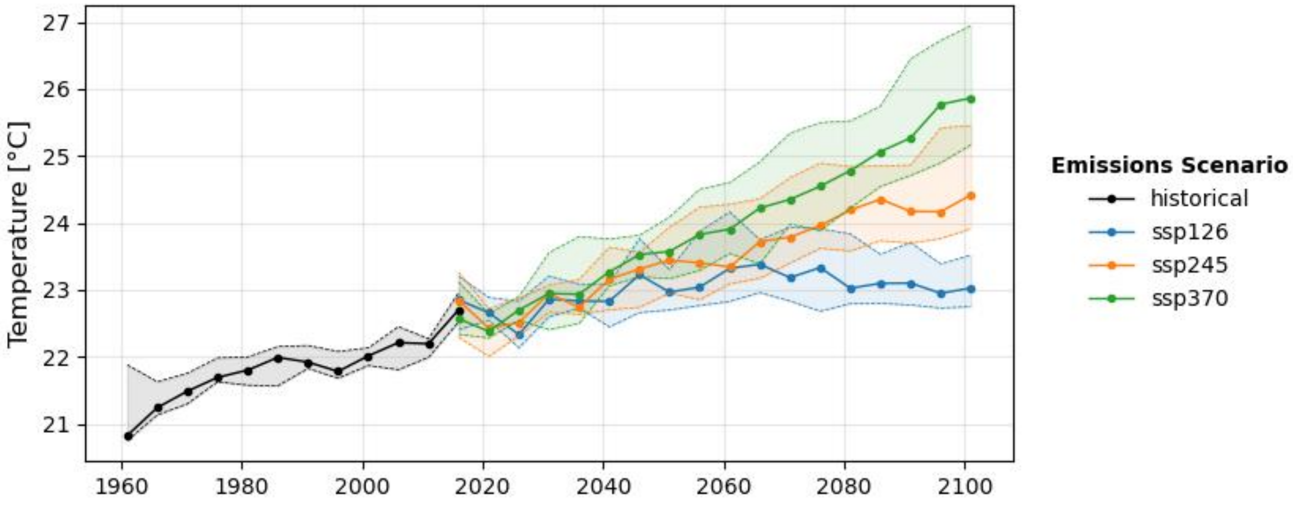


Figure 18: Climate projections for Auckland showing summer maximum temperature (December-February).

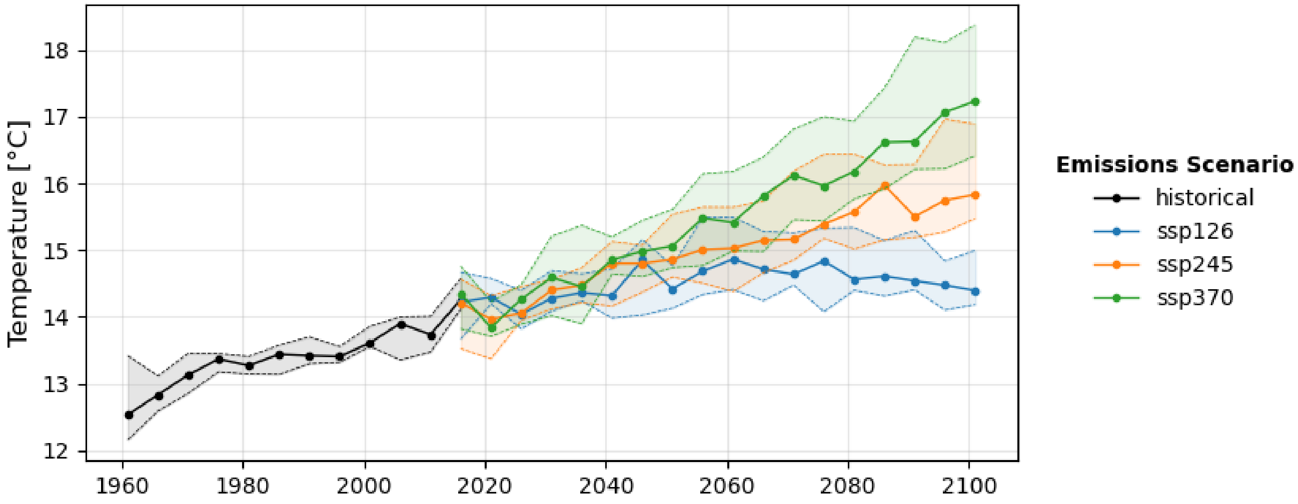


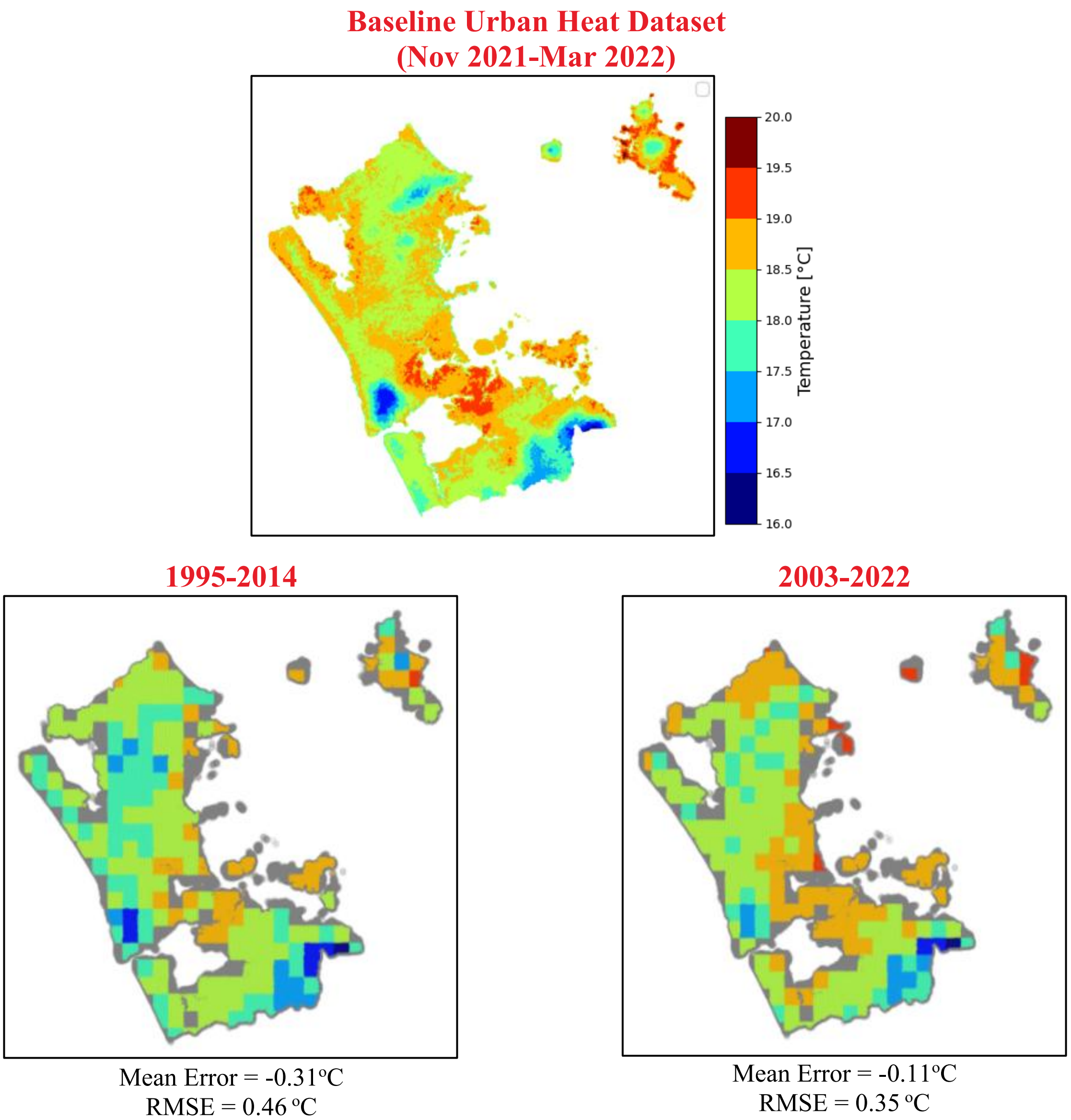
Figure 19: Climate projections for Auckland showing summer minimum temperature (December-February).

A.1.2 Reference Period

Four candidate reference periods were tested to identify the most appropriate 20-year period to represent the baseline conditions within the climate projections:

- **1995-2014**: A typical historical reference period prior to 2015. In the projection dataset, this period is based entirely on historical climate data, with no emissions scenarios applied. This period is used by Earth Sciences New Zealand.
- **2003-2022**: Uses 2022 as the final year of the reference period, aligning closely with the 2021–2022 baseline urban heat dataset. This period includes historical data (2003–2014) and projected data (2015–2022) under different emissions scenarios.
- **2016-2035**: Uses 2022 as the midpoint of the reference period and is fully based on projected climate data under varying emissions scenarios.
- **2021-2040**: Uses 2022 as the start year of the reference period and is also fully based on projected climate data under varying emissions scenarios.

To assess the suitability of each period, mean error and root mean square error (RMSE) were calculated relative to the baseline urban heat dataset. These metrics represent average temperature differences across Auckland and are shown in Figure 20.



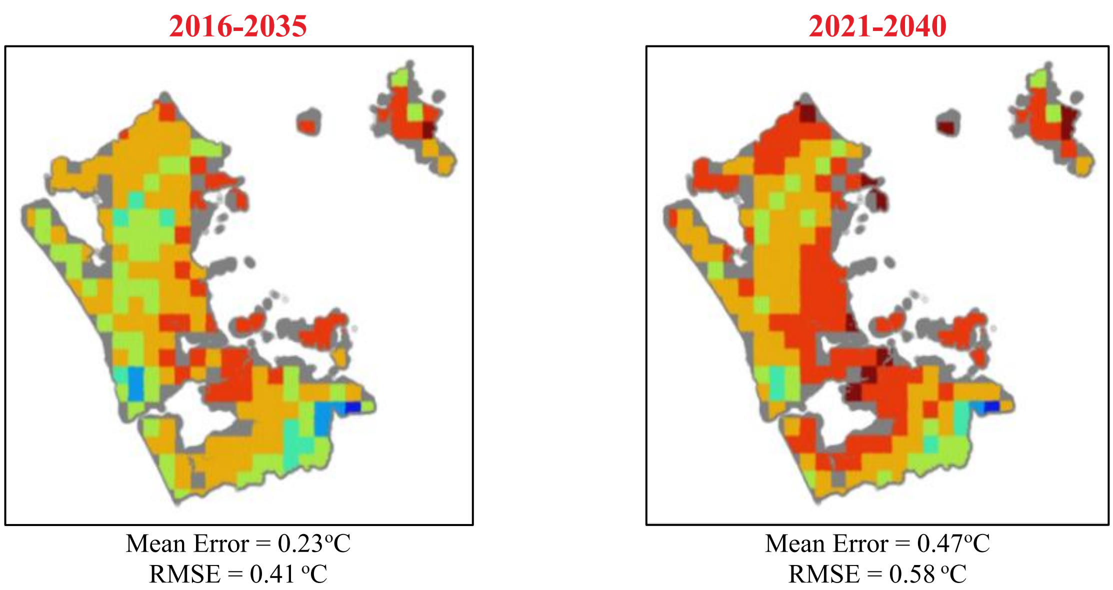


Figure 20: Analysis of various reference periods.

The 1995-2014 and 2003-2022 periods show negative mean errors, where temperatures are below the urban heat baseline. The 2016-2035 and 2021-2040 time periods have positive mean errors with higher temperatures than the urban heat baseline.

The 2003–2022 period has the lowest mean error and RMSE and was therefore selected as the reference period for this analysis.

A.1.3 Future Temperature Adjustments

The future temperature adjustments differ between climate scenarios, as seen in Figure 21 for the 2050 and 2090 period for SSP3-7.0. However, the spatial variation of the climate projection dataset across Auckland is small, mostly within 0.5°C. Therefore, it is expected the distribution of hot spots and cold spots will be dominated by the baseline urban heat analysis results.

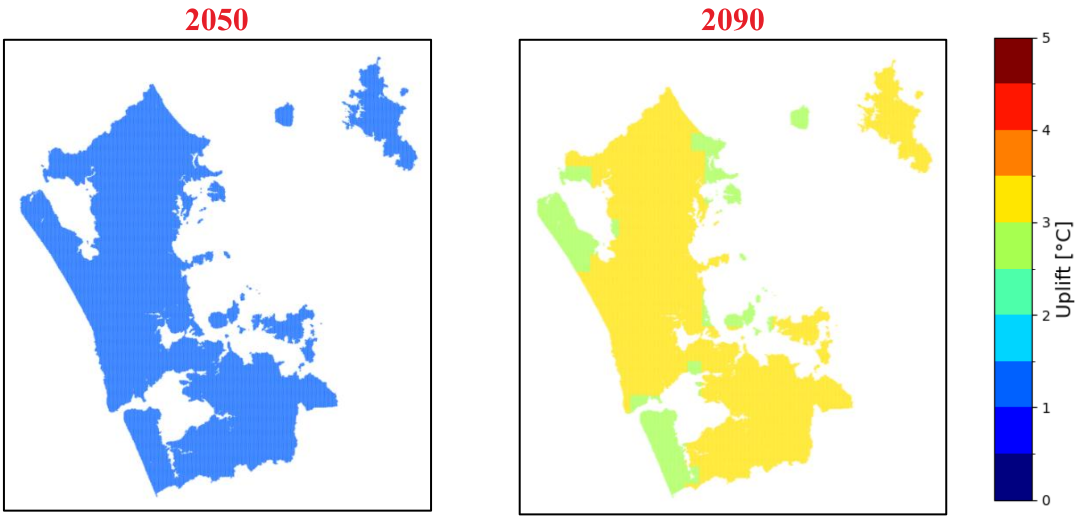


Figure 21: Future temperature adjustments across Auckland of daily mean summer temperature.

A.1.4 Monthly Climate Change Adjustments

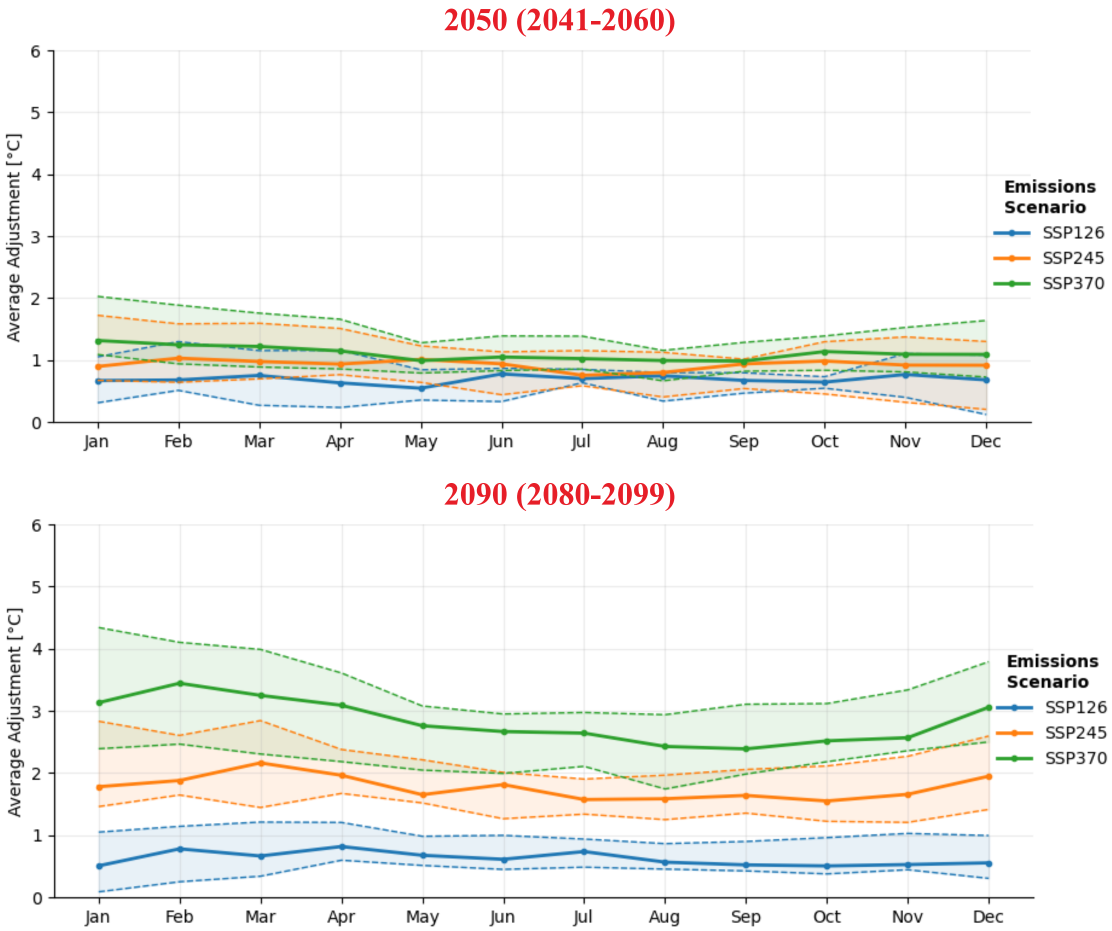
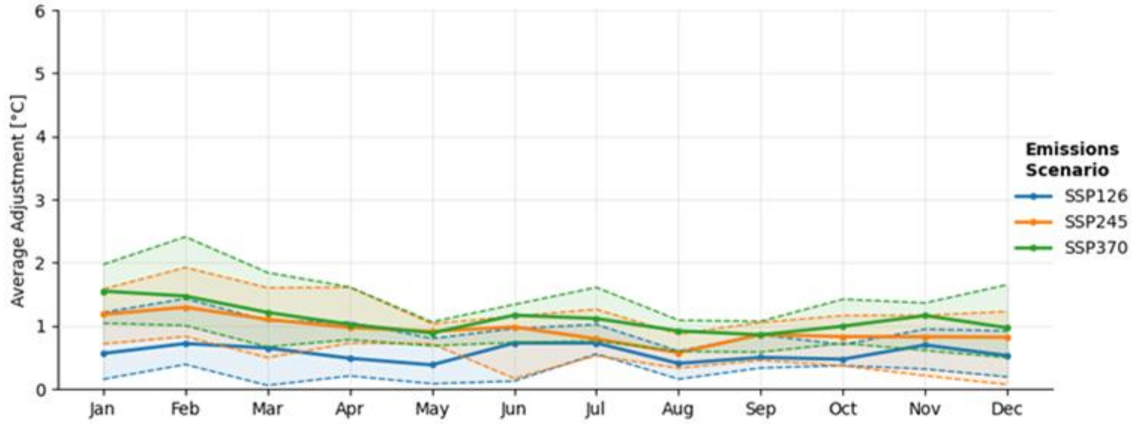


Figure 22: Maximum temperature monthly uplift from the reference period (2003-2022).

2050 (2041-2060)



2090 (2080-2099)

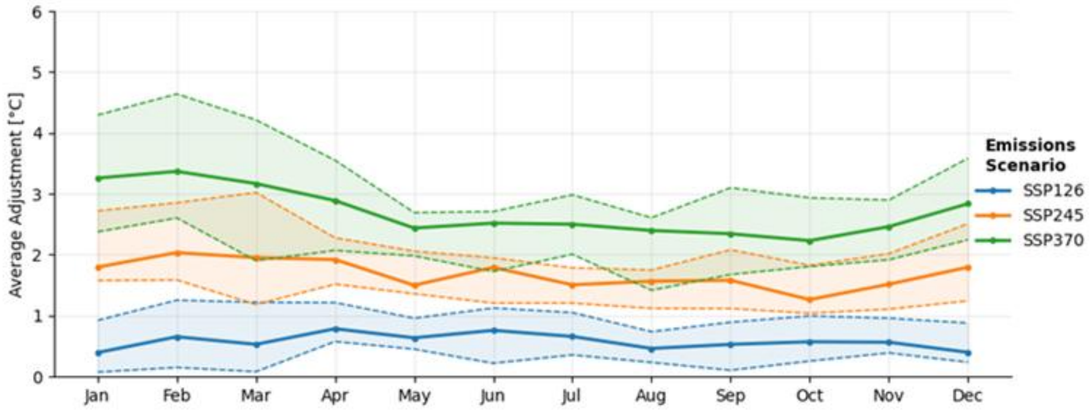


Figure 23: Minimum temperature monthly uplift from the reference period (2003-2022).

A.2 Appendix B – Heat Metrics (SSP1-2.6)

A.2.1.1 Heat Maps

Hot Days

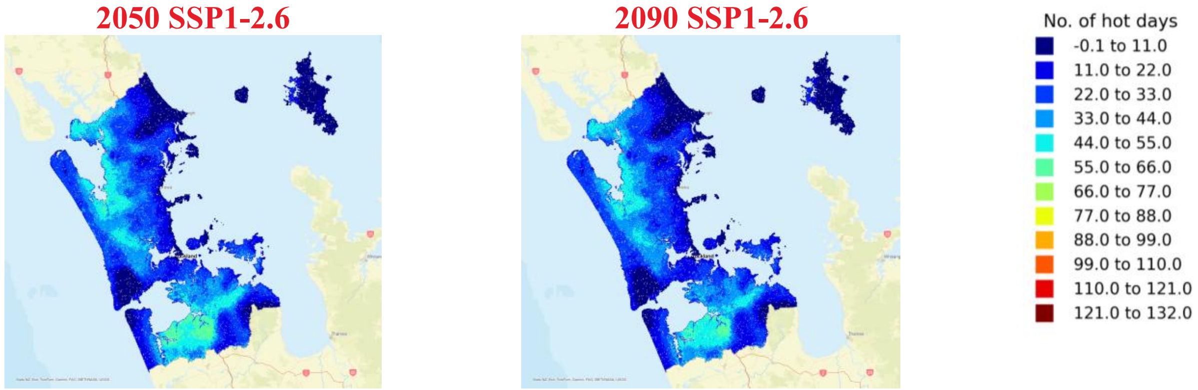


Figure 24: Hot days projected over Auckland for the SSP1-2.6 scenario.

Very Hot Days

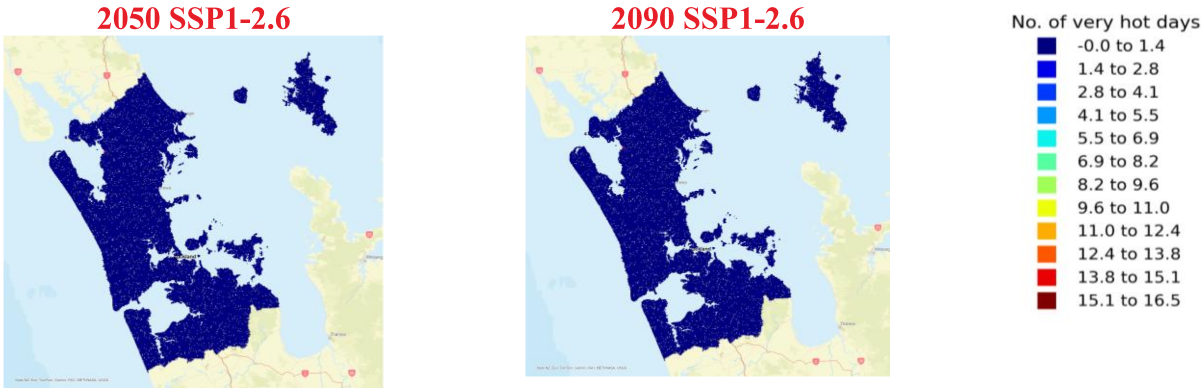


Figure 25: Very hot days projected over Auckland for the SSP1-2.6 scenario.

Heatwave Frequency (Daytime)

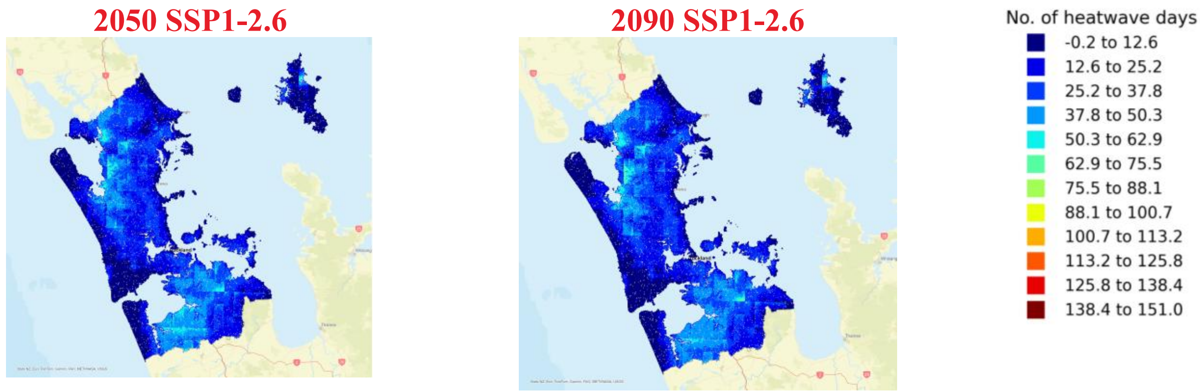


Figure 26: Heatwave frequency (daytime) projected over Auckland for the SSP1-2.6 scenario.

Heatwave Duration (Daytime)

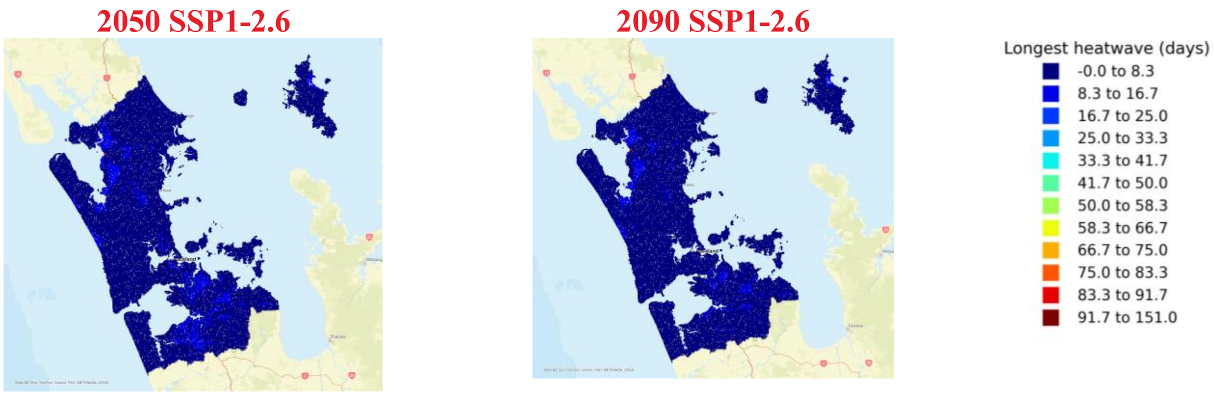


Figure 27: Heatwave duration (night-time) projected over Auckland for the SSP1-2.6 scenario.

Hot Nights

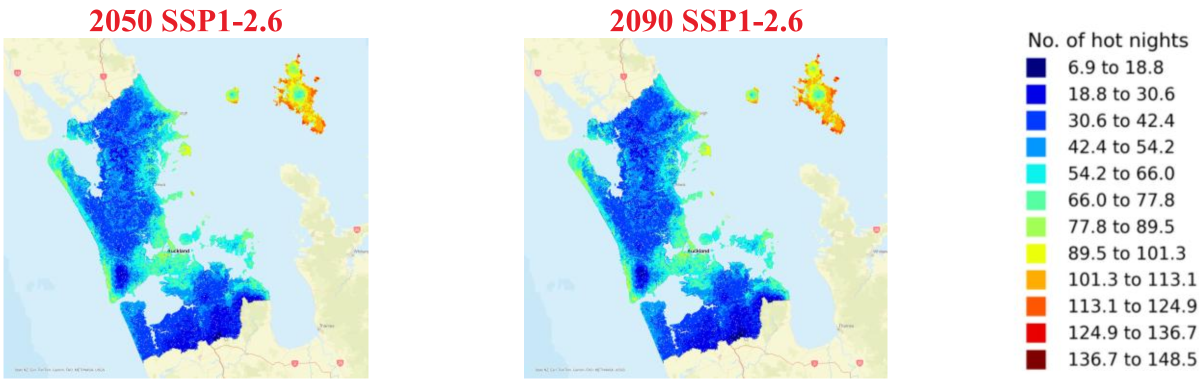


Figure 28: Hot nights projected over Auckland for the SSP1-2.6 scenario.

Heatwave Frequency (Night-time)

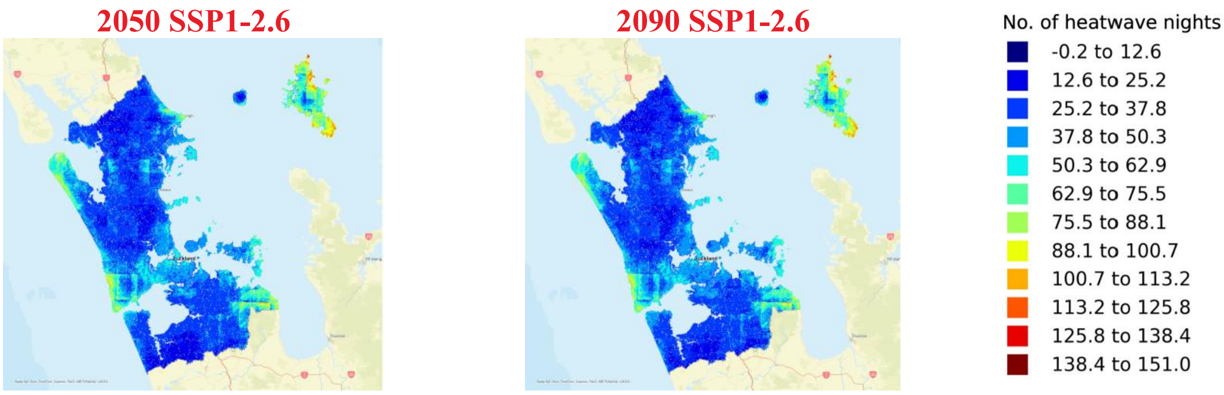


Figure 29: Heatwave frequency (night-time) projected over Auckland for the SSP1-2.6 scenario.

Heatwave Duration (Night-time)

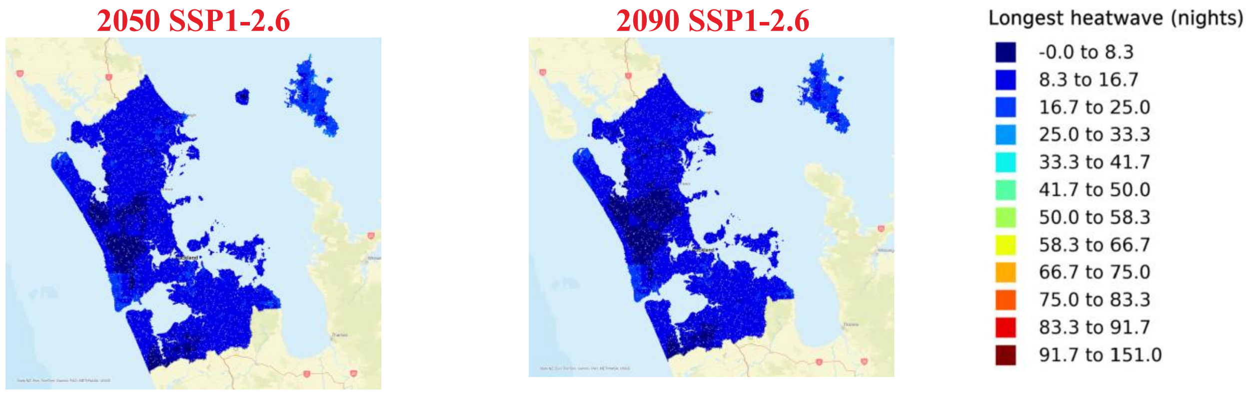


Figure 30: Heatwave duration (night-time) projected over Auckland for the SSP1-2.6 scenario.

A.3 Appendix C – Heat Metrics (95th Percentile)

This appendix presents heat metric results using the 95th percentile temperatures. The average threshold for a hot night was calculated as 17.2°C (16.8°C for the 90th percentile). As the thresholds are more extreme for the 95th percentile compared to the 90th percentile, heat events are usually lower than those presented in Section3. Future Climate Results.

		2050 (2041-2060)			2090 (2080-2099)		
Threshold Indices	**Baseline**	**SSP1-2.6**	**SSP2-4.5**	**SSP3-7.0**	**SSP1-2.6**	**SSP2-4.5**	**SSP3-7.0**
Daytime							
Hot Days (>25°C)	16.0	27.1	31.3	39.8	25.5	55.9	87.8
Very Hot Days (>30°C)	0.0	0.0	0.0	0.0	0.0	0.2	2.8
Heatwave Frequency	8.1	16.5	21.4	26.9	16.6	46.4	90.0
Longest Heatwave	2.9	4.7	5.4	6.2	4.5	8.7	17.3
Night-time							
Hot Nights	90.7	38.7	55.9	57.5	37.8	75.2	103.1
Heatwave Frequency	19.2	29.0	42.7	45.6	28.3	62.9	96.4
Longest Heatwave	8.1	9.9	12.0	12.6	9.7	15.3	25.4

Table 6: Heat event metrics using 95th percentile thresholds (averaged across Auckland) for the 50th percentile model.

		2050 (2041-2060)			2090 (2080-2099)		
Threshold Indices	**Baseline**	**SSP1-2.6**	**SSP2-4.5**	**SSP3-7.0**	**SSP1-2.6**	**SSP2-4.5**	**SSP3-7.0**
Daytime							
Hot Days (>25°C)	16.0	+11.1	+15.3	+23.8	+9.4	+39.9	+71.8
Very Hot Days (>30°C)	0.0	+0.0	+0.0	+0.0	+0.0	+0.2	+2.8
Heatwave Frequency	8.1	+8.4	+13.3	+18.8	+8.5	+38.2	+81.9
Longest Heatwave	2.9	+1.8	+2.5	+3.3	+1.6	+5.8	+14.4
Night-time							
Hot Nights	90.7	+-52.0	+-34.8	+-33.2	+-53.0	+-15.6	+12.4
Heatwave Frequency	19.2	+9.8	+23.6	+26.4	+9.2	+43.8	+77.2
Longest Heatwave	8.1	+1.8	+3.8	+4.4	+1.6	+7.2	+17.3

Table 7: Change in heat event metrics from the baseline using 95th percentile thresholds (averaged across Auckland) for the 50th percentile model.

A.3.1.1 Heat Maps

Heatwave Frequency (Daytime)

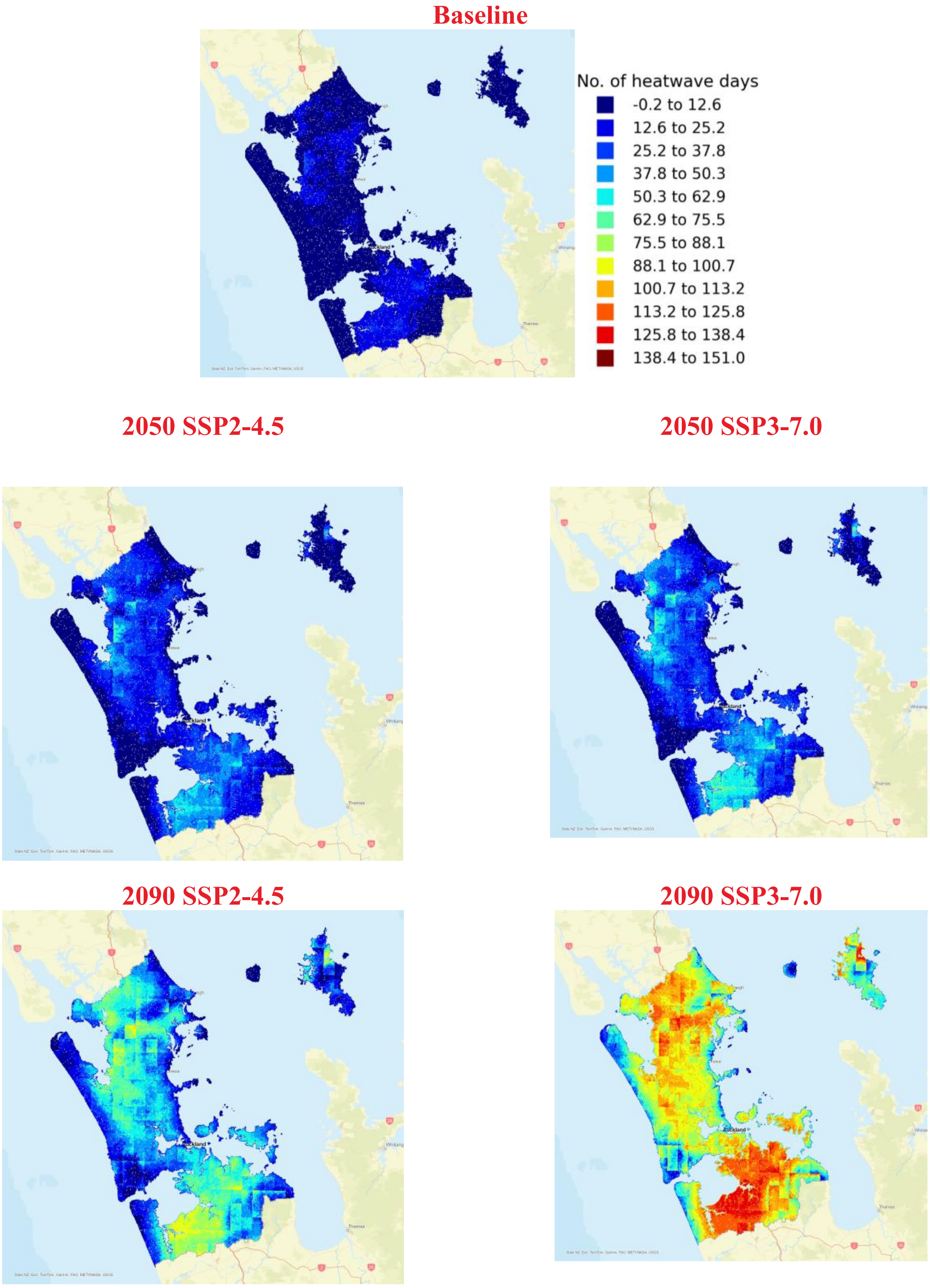


Figure 31: Heatwave frequency (daytime) projected over Auckland, where metrics are derived using the 95th percentile as a threshold.

Heatwave Duration (Daytime)

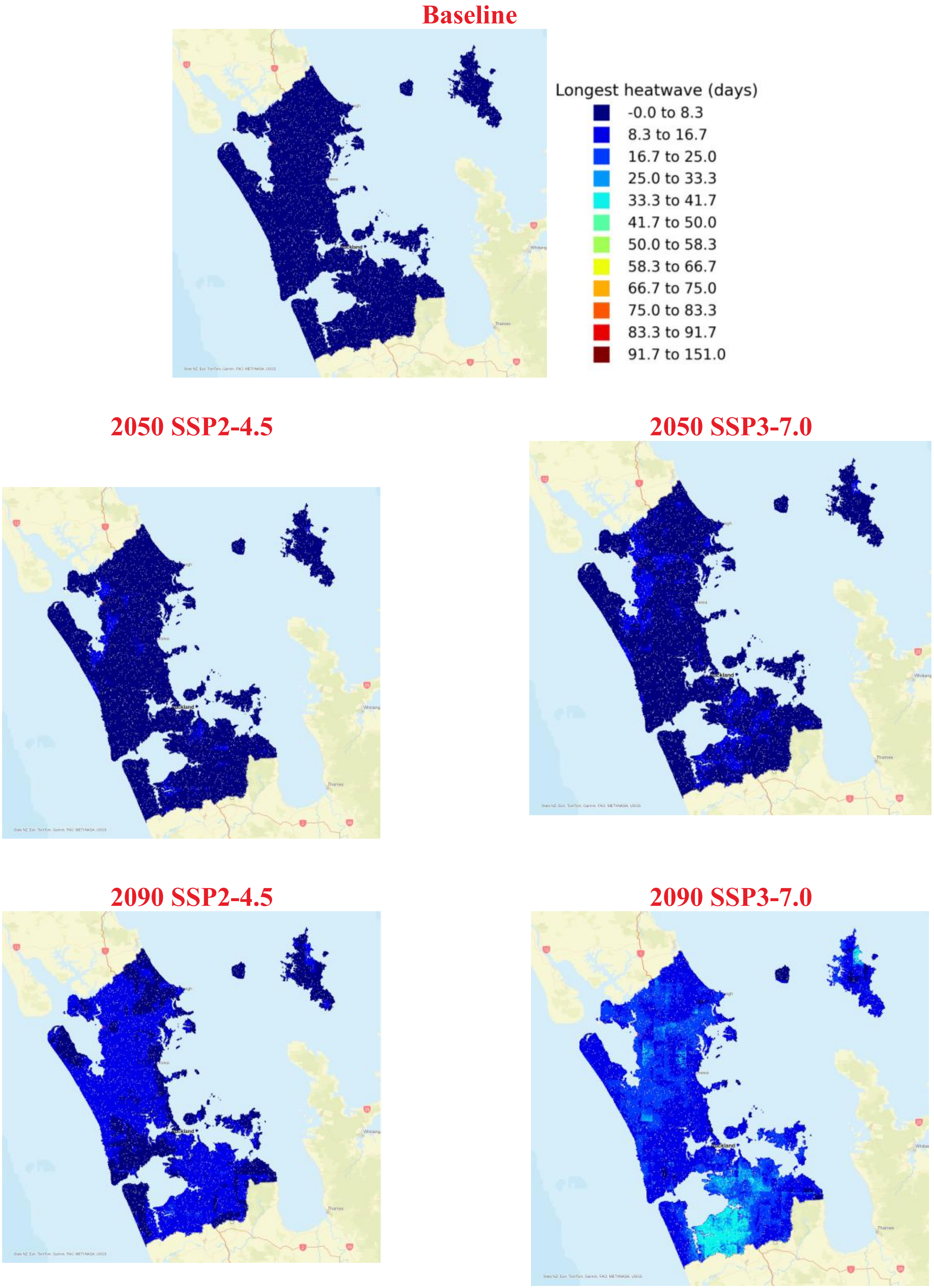


Figure 32: Heatwave duration (daytime) projected over Auckland, where metrics are derived using the 95th percentile as a threshold.

Hot Nights

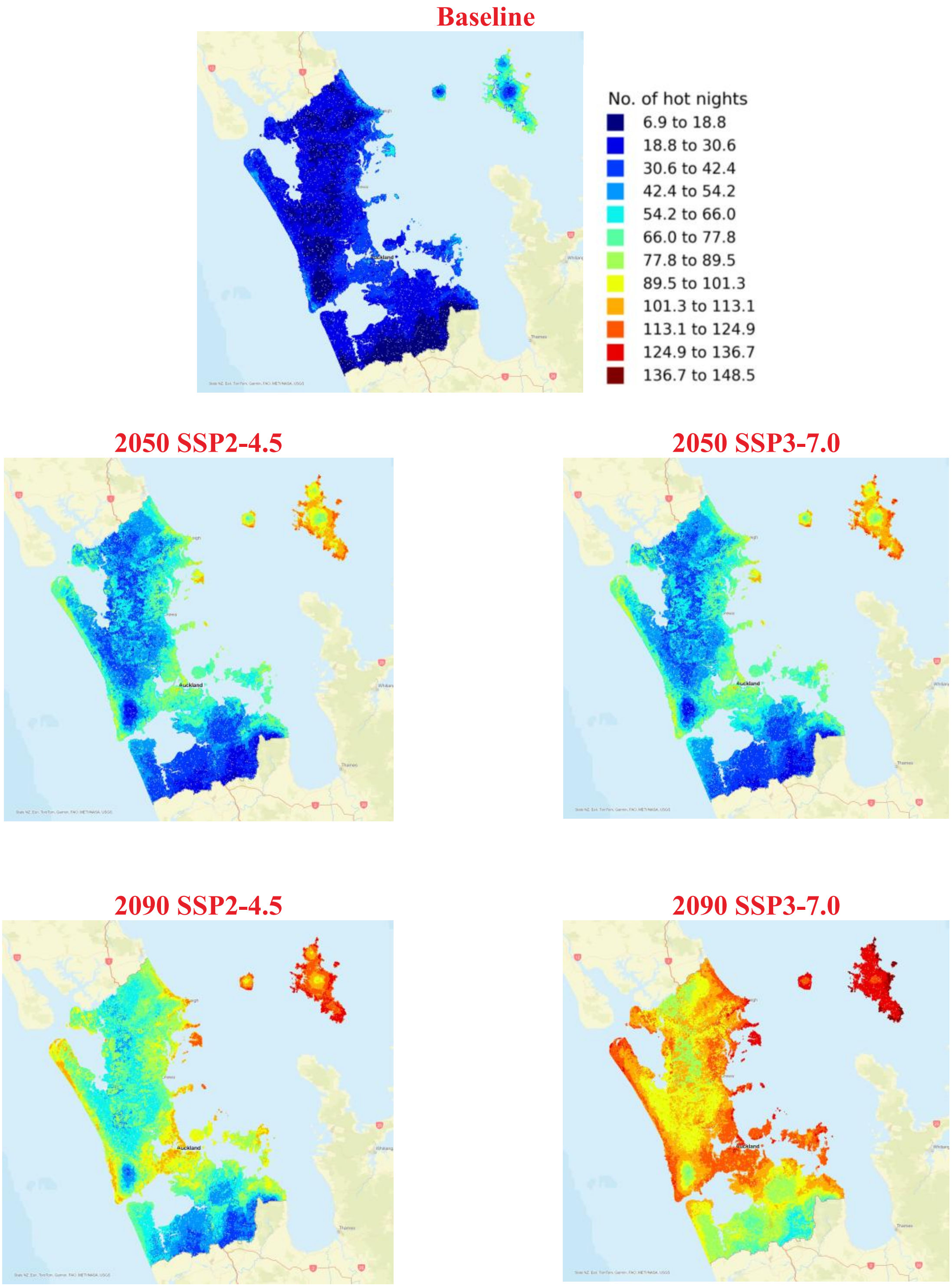


Figure 33: Hot nights projected over Auckland, where metrics are derived using the 95th percentile as a threshold.

Heatwave Frequency (Night-time)

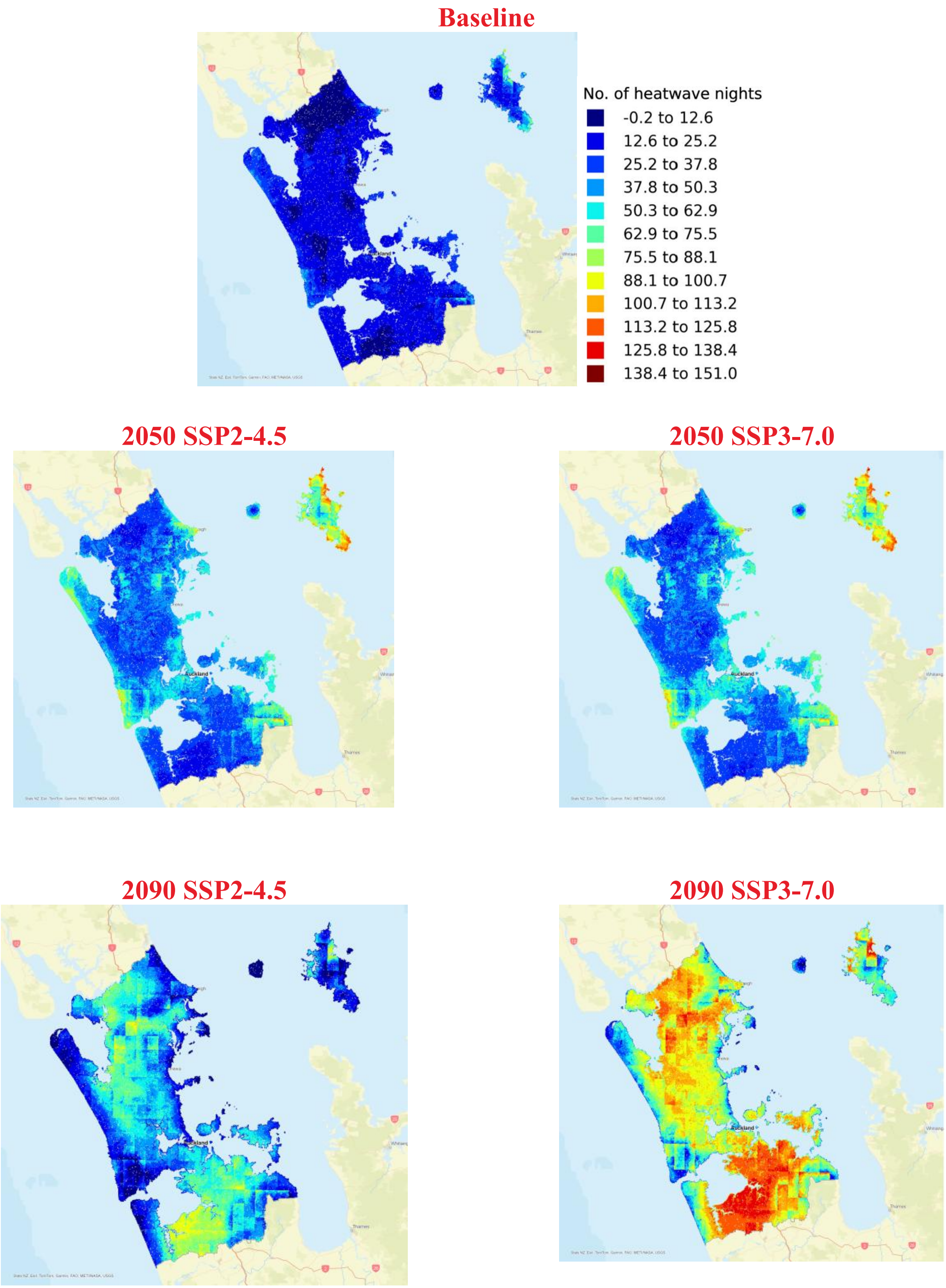


Figure 34: Heatwave frequency (night-time) projected over Auckland, where metrics are derived using the 95th percentile as a threshold.

Heatwave Duration (Night-time)

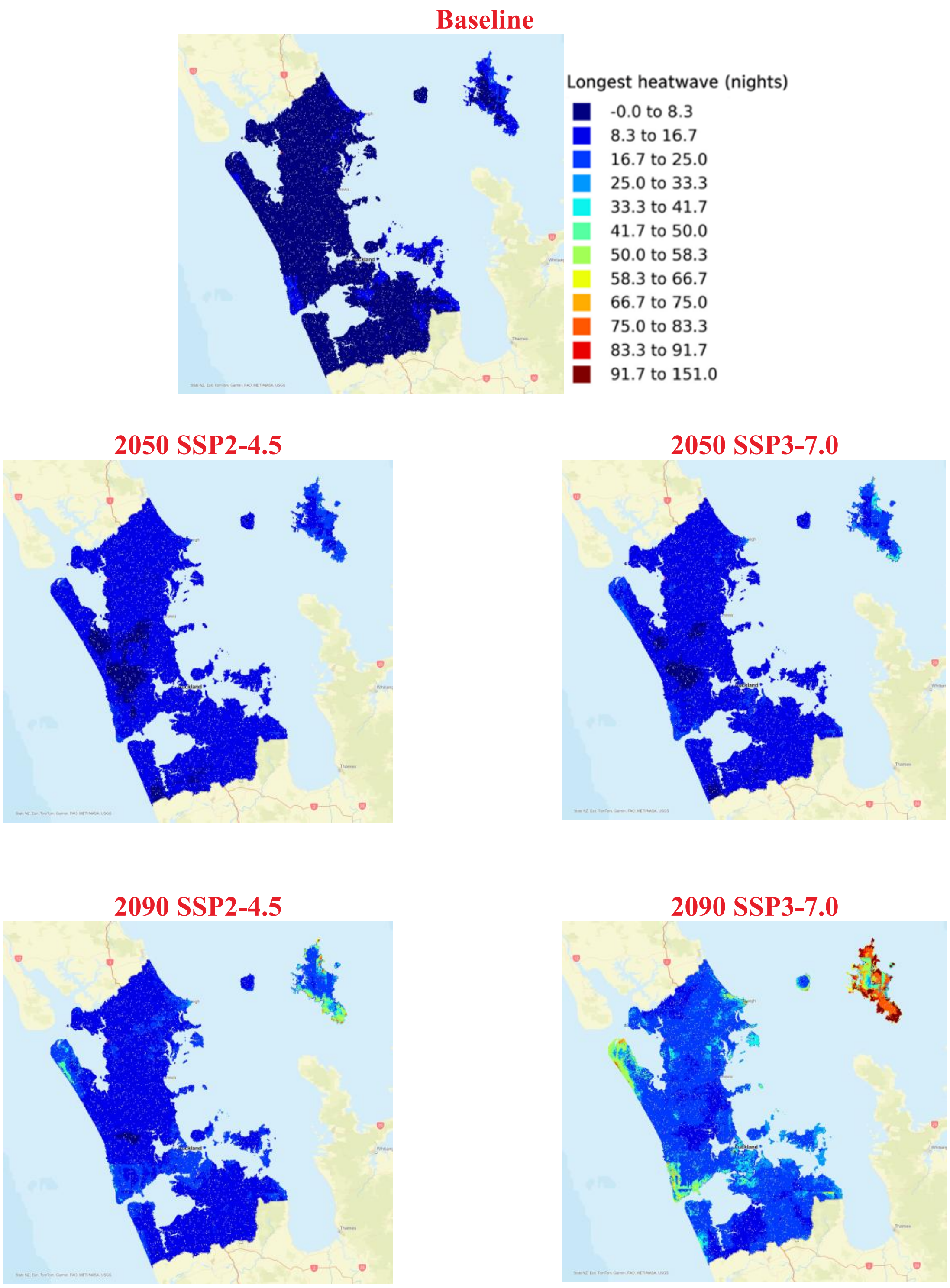


Figure 35: Heatwave duration (night-time) projected over Auckland, where metrics are derived using the 95th percentile as a threshold.