

Climate change eclipses La Niña cooling in Australia to drive extreme heatwave and heightened fire risk

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Main findings

- Heatwaves cause more deaths in Australia than all other natural hazards combined. They are already placing acute pressure on Australia's health system, with impacts extending beyond physical illness. During recent heat events, emergency departments in Melbourne and Sydney reported sharp increases in the number of patients, particularly among elderly people, those living in overheated buildings without access to cooling, outdoor workers, and individuals with pre-existing conditions. In regional South Australia, clinicians also reported worsening mental health presentations linked to extreme heat.
- Vulnerability to heat has shifted over time, from primarily elderly people living alone to populations facing socioeconomic disadvantage and chronic illness, including homeless people and migrants, highlighting the need for adaptive, equity-focused heat-health policies.
- The extreme heat, strong winds, and unusually dry conditions in Victoria in late 2025 combined to create extreme fire weather conditions across a large area which resulted in multiple large, fast-spreading wildfires. These conditions make wildfires very difficult to control, and increase the likelihood of property destruction and deaths.
- This heatwave was the most severe in six years. The 3-day maximum temperatures in the study region observed in 2026 have a return time of about 5 years in today's climate, which has warmed globally by 1.3°C.
- When combining the observation-based analysis with climate models to quantify the role of climate change in the 3-day heat event, we conclude that climate change made the extreme heat about 1.6°C hotter. While the discrepancy between observations and models is smaller in this region than in other parts of the world, climate models still show a systematically smaller change in likelihood and intensity than observation based assessments. Based on the available evidence we conclude that similar events are about 5 times more likely to occur now than they would have been in a preindustrial climate without human-caused warming; however, this is likely an underestimate.
- After a further 1.3°C of global warming – the level projected to be reached by the end of the century under current policies – the likelihood and intensity of such events are projected to continue to increase, becoming 1.5°C warmer and a further 3 times as likely.
- We further assess the influence of natural modes of variability, such as ENSO and the IOD on the likelihood and intensity of the event in the study region. We find that while the IOD does have a small influence, the current phase of ENSO, a weak La Niña before the summer, reduced the chances and severity of this heatwave. Our best estimates indicate that La Niña made such extreme temperatures less likely, by roughly 20–45 per cent and lowered 3-day maximum temperatures by about 0.3–0.5°C. While natural climate variability reduced the likelihood of this heatwave, the increase in risk driven by climate change is much larger and ultimately dominant.
- The heat experienced in New Zealand's North Island was a one-in-five-year event in today's climate. Without human-induced climate change, such temperatures would have been much

rarer. Given the affected population is not well adapted to heat, and no heat alerts were in place, severe impacts on vulnerable populations are expected.

- Despite Australia's advanced warning systems, many people, particularly elderly and vulnerable populations do not recall heatwave alerts or act on them. With strong evidence showing that risk awareness influences behavioural response, there is the need for targeted, impact-based communication to translate warnings into effective risk reduction, including media reporting that avoids stereotypical imagery that downplays risk (e.g. beach and ice-cream images).
- Record daytime electricity demand was met more smoothly than in past heatwaves, largely due to abundant renewable generation. Solar power alone supplied over 60% of midday electricity, and even more when combined with wind and hydro, helping to keep prices stable. This contrasts sharply with earlier heatwaves, when coal and gas plants struggled to meet demand.
- Heat impacts are often most severe in cities, where geography and the urban heat-island effect intensify temperatures, especially in neighbourhoods with high concentrations of vulnerable populations that face additional indoor heat that surpass health safety levels for several consecutive days during heat events. While progress has been made on heat-resilient urban design, it remains a critical priority as people are pushed beyond their coping abilities. At the same time, it is important not to focus exclusively on cities: significant heat impacts also occur beyond urban areas, particularly in rural areas among Torres Strait Islander and Aboriginal communities, where risks are frequently under-recognised.

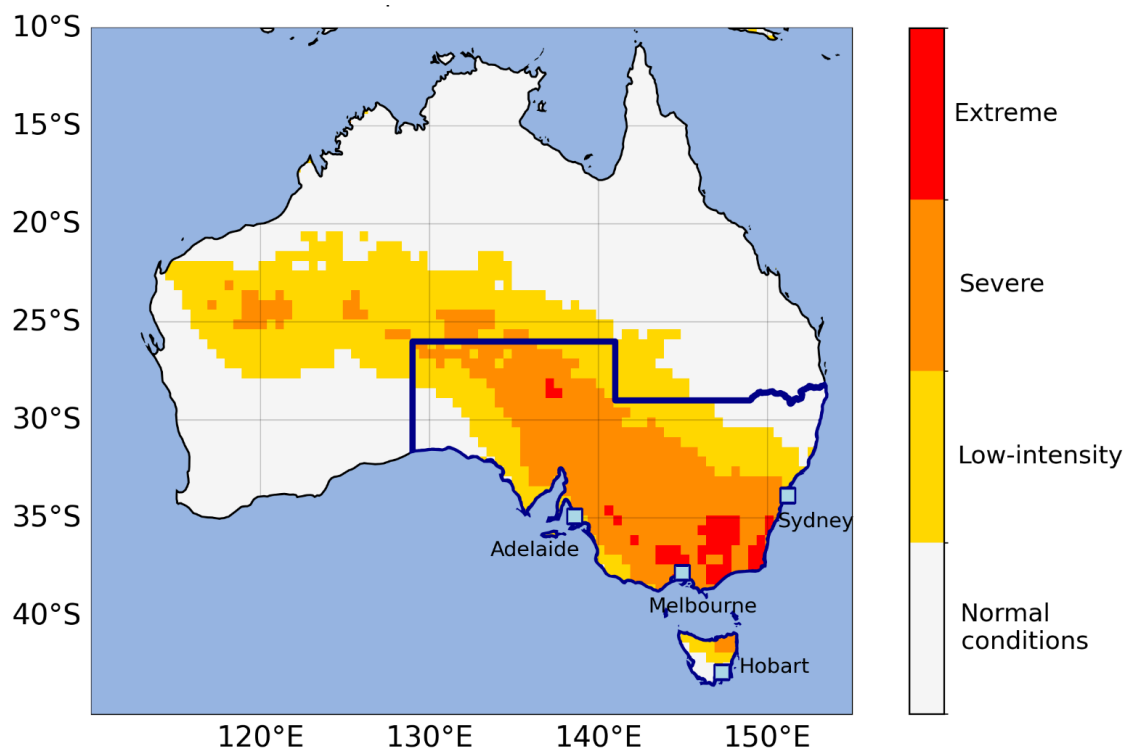


Figure 1.1: Heatwave severity classification based on the Excess Heat Factor over land areas in Australia for 7-9th January 2026. This metric combines the anomalies of the current conditions relative to both short- and long-term comparison periods and is used by the Australian Bureau of Meteorology for heatwave forecasting and alerts ([Nairn & Fawcett, 2016](#); [Nairn & Fawcett, 2015](#)).

1 Introduction

From the 5th of January, 2026, until the weekend of the 10th, Southeastern Australia was experiencing the most severe heatwave since the summer of 2019-20. In many of the densely populated cities of southern and eastern Australia, temperatures close to or above 40°C were recorded during the period from 7-9th January: Observatory Hill in Sydney reached 42.2°C while Penrith in western Sydney recorded 42.5°C, Melbourne airport hit 44.4°C, Adelaide recorded 42°C, and Canberra airport reached 39.2°C ([Bureau of Meteorology, 2026](#)), with even hotter conditions recorded across parts of regional Victoria and New South Wales. The heatwave impacted extensive areas across the continent, including Western Australia, South Australia, Victoria, New South Wales, the Australian Capital Territory, and Tasmania. Large population centres, such as Melbourne, Adelaide, and western Sydney, as well as inland regions including the Mallee, Murraylands, and Riverina, experienced extreme heat ([IOAir, 2026](#)). Many parts of New Zealand also experienced very high temperatures when the hot and dry air mass moved eastwards on the 10th and 11th of January ([RNZ, 2026](#)).

Heatwaves are one of the deadliest natural hazards, leading to more deaths in Australia than all other natural hazards combined ([Coates et al., 2014](#)). While this heatwave affected a population accustomed to high temperatures, all populations have physiological limits (e.g. [Vanos et al., 2023](#)), and the dangers of extreme temperatures such as those observed are often underestimated. Although heatwaves put everyone at risk, some individuals are more acutely vulnerable ([Tong et al., 2026](#); [Amoatey et al., 2025](#); [Bhatta et al., 2023](#); [Wang et al., 2023](#); [Adnan et al., 2022](#)). This includes older individuals, young children, individuals with pre-existing medical conditions, people who are socially isolated, people who are houseless, people without easy access to air-conditioning, and outdoor workers. Hospitals reported a surge in heat-related illnesses, with a 25% increase in emergencies in Melbourne ([ABC, 2026](#)). Animal suffering is widespread, affecting koalas, insects, such as honeybees and ants ([Phys.org, 2026](#)), as well as bats, who have died in their thousands ([The Guardian, 2026](#)).

Heatwave conditions across large areas of South Australia, Victoria, New South Wales, and the Australian Capital Territory were classified as severe to extreme and persisted for six days, until the 10th of January. From Friday the 9th of January, the passage of a cold front accompanied by strong winds affected Victoria and New South Wales, creating highly dangerous fire weather conditions comparable to those preceding the 2009 Black Saturday bushfires ([AA, 2026](#)). These extremes followed warmer and drier than average conditions over large parts of Victoria in the lead up to January 2026. In 2025, rainfall over the state was 18% below the 1961-1990 mean ([BoM, 2025](#)) – a continuation of a longer term drying trend going back to February 2024 – leading to large areas of drier than normal fuel, increasing the chance of fire activity. As a result, substantial portions of southern and western Victoria were flagged as expecting heightened risk in the seasonal outlooks issued in Spring and Summer of 2025 (AFAC, [2025a](#), [2025b](#)). The combination of long-term dryness, extreme heat and high winds increased the likelihood of extreme fire behaviour for any fires that did occur, making them harder to control. At the peak of fire activity, there were at least 18 active emergency warnings spread out over a wide spatial area, including across Victoria and parts of New South Wales, straining fire management resources ([VIC Emergency, 2026](#)).

Several antecedent factors differ from those observed during the 2019–2020 and 2009 events, including less severe drought conditions. Additionally, the implementation of a national fire danger

rating system ([AFDRS](#)) and increased public awareness of fire preparedness (e.g. [Lucas et al., 2022](#)) represent important advances in risk mitigation. These factors may have reduced the likelihood of a catastrophic fire event similar to those associated with previous severe heatwaves, but that does not mean there is no risk, especially given the presence of significant fires already burning in Victoria.

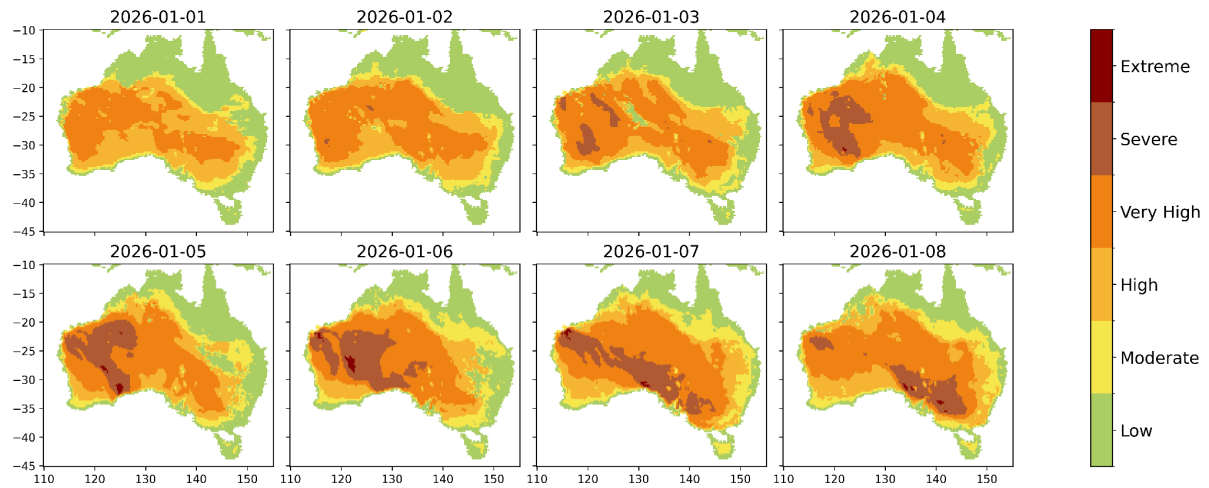


Figure 1.2: McArthur Forest Fire Danger Index (FFDI) values over the first eight days of January, with classes (0-5 low, 5-12 moderate, 12-25 high, 25-50 very high, 50-75 severe, 75+ extreme) taken from [Holgate et al. \(2017\)](#).

The heatwave was driven by the incursion of an exceptionally hot and dry air mass originating in northwestern Australia and extending into the southern and eastern parts of the country. This air mass was transported by sustained northwesterly flow and intensified by a slow-moving high-pressure system situated over the Tasman Sea, which effectively inhibited the intrusion of cooler air into the affected regions. These conditions allowed persistent sunshine and reduced overnight cooling, enabling temperatures to build and remain well above average for several days. The event coincided with a weak La Niña and MJO (Madden-Julian Oscillation) phase 6, conditions known to increase the likelihood of summer heatwaves in Victoria by favouring persistent hot weather patterns ([Parker et al., 2014](#)).

At the upper levels of the atmosphere, a high-pressure system over southern Australia promoted subsidence, causing air to descend and compress near the surface, thereby amplifying surface temperatures. Widespread clear-sky conditions have further enhanced daytime solar heating. These atmospheric processes are occurring against the backdrop of one of Australia's warmest summers on record, contributing to the exceptional intensity of the heatwave ([IOAir, 2026](#)).

1.1 Extreme heat in southern Australia

Extreme heat events are the most straightforward and robust of all weather and climate extremes experienced in Australia to attribute to human-induced climate change ([Lane et al 2023](#)). Previous attribution studies at regional scales across Australia have consistently identified a significant influence of anthropogenic climate change on extreme heat events. For example, the “Angry Summer” of 2012/13, Australia’s hottest summer on record until 2018/19, was found to be at least five times more likely to occur due to human influence ([Lewis and Karoly, 2013](#)). During this summer, both the frequency and intensity of heatwaves were shown to have increased

as a result of anthropogenic forcing ([Perkins et al., 2014](#)). Annual maximum TX7x temperatures as observed in summer 2019/2020 over the southeast of Australia were found to be by 1-2°C warmer in observations, but although climate models simulated a warming trend, they underestimated the observed increase in extreme temperatures and overestimated their variability ([Van Oldenborgh et al. 2021](#)).

Additional attribution studies have similarly demonstrated a human influence on extreme heat across Australia, including the May 2014 heatwave ([Perkins and Gibson, 2015](#)), record-breaking October heat in 2015 ([Hope et al., 2016](#)), and extreme heat in Brisbane during November 2014 ([King et al., 2015](#)). However, attribution becomes more uncertain at smaller spatial scales; for instance, human influence on extreme heat was less clear for the city of Melbourne in January 2014 ([Black et al., 2015](#)). Analysis on the 2009 Southeast Australian Heatwave found that human-induced climate change increased the intensity of the event by 3°C ([Abhik et al 2023](#)), and human influence on mortality during the same heatwave has also been reported. This resulted in a 20% increase in the occurrence of extreme heat-related mortality during the 2009 event, as well as a doubling in frequency of similar mortality events over Victoria ([Perkins-Kirkpatrick et al 2025](#)).

The latest [IPCC report](#) also confirmed that there is very robust evidence of long-term changes in temperature extremes across Australasia more broadly, stating that since 1950, the number of warm days and warm nights has very likely increased, while the number of cold days and cold nights has decreased. Overall, the literature provides robust evidence of a human contribution to the observed increase in the intensity and frequency of hot extremes, alongside a decrease in the intensity and frequency of cold extremes across the region.

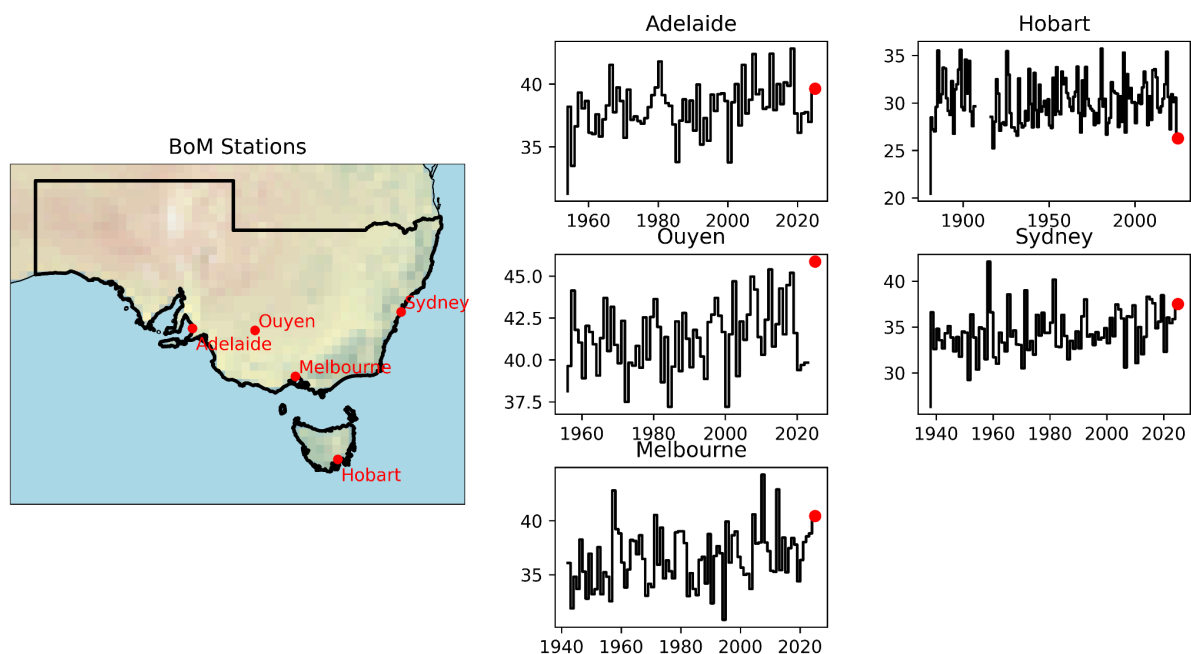


Figure 1.3: Annual maximum 3-day averaged daily maximum temperatures in southern Australia. Station data trends for all four regional capitals, and the town of Ouyen where the heat was

record-breaking (2024 data missing). Station IDs for each location were: Adelaide, 023034; Hobart, 094029; Melbourne, 087031; Ouyen, 076047; Sydney, 066037.

In New Zealand, working group 1 of the sixth assessment report of the IPCC found increasing trends in heat extremes in New Zealand, but that the evidence for attributing this trend to human-induced climate change was low ([Masson-Delmotte et al., 2021](#)). More recent studies on heat extremes confirm the intensification in heat extremes in recent decades, with the hottest days in populated areas becoming approximately 0.5C hotter in the past 20 years ([Harrington & Frame, 2022](#)), and projected further intensification with warming ([Lewis et al., 2025](#)). Nonetheless, to our knowledge no attribution of this rise in heat extremes to present human-induced climate change exists.

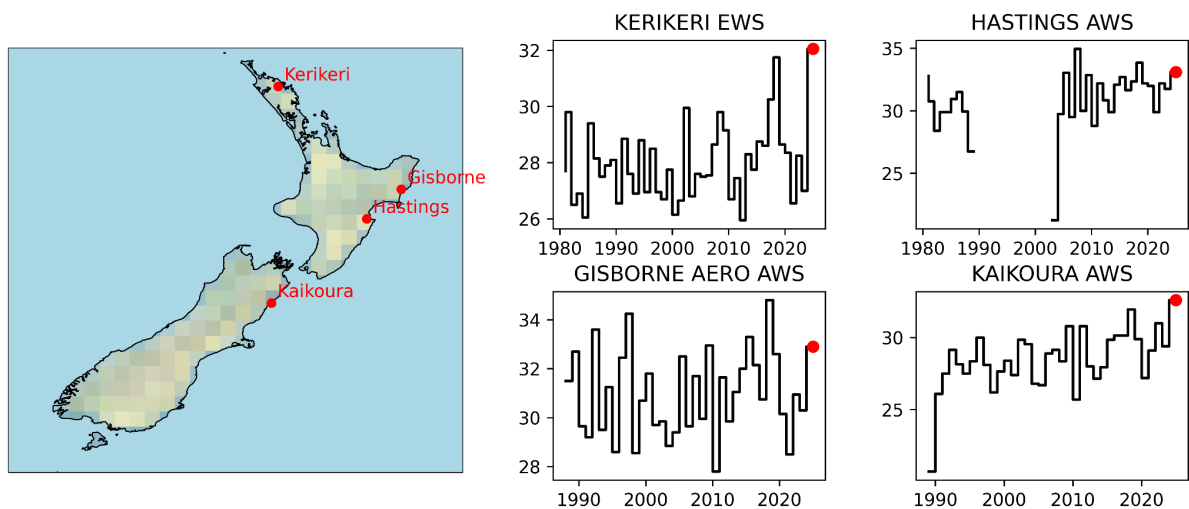


Figure 1.4: Annual maximum 3-day averaged daily maximum temperatures in northern New Zealand. Record breaking temperatures of 32.05°C and 32.60°C were recorded in Kerikeri and Kaikoura.

1.2 Event Definition

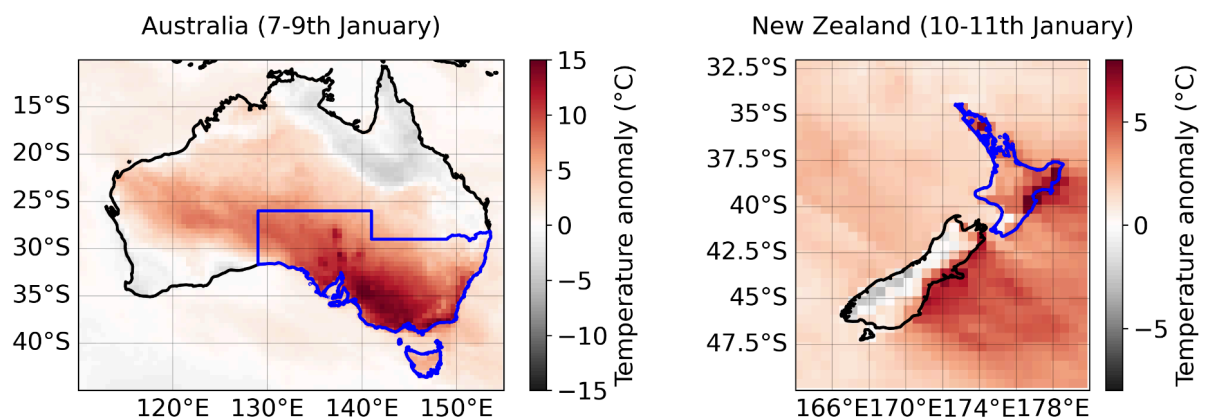


Figure 1.5: Anomalies of 3-day daily maximum temperatures from 7-9th January 2026 over Australia (left) and 2-day daily maximum temperatures from 10-11th January 2026 over New Zealand (right)

with respect to mean summer (December-February) daily maximum temperatures over the 1991-2020 climatological period. The study regions are shown in blue. Data: ERA5.

In this report, we characterize the heat in two ways to capture the extremes experienced by those most affected. These event definitions are shown in Fig. 1.5 and described as follows:

- **Australia (full attribution)** - Annual (July-June) maximum 3-day mean of daily maximum temperatures over the study region in southern and eastern Australia, comprised of Victoria, New South Wales, South Australia and Tasmania (henceforth Tx3x)
- **New Zealand (observational trends only)** - Annual (July-June) maximum 2-day mean of daily maximum temperatures over the North Island of New Zealand (henceforth Tx2x)

We study the influence of anthropogenic climate change by comparing the likelihood and intensity of similar Tx3x and Tx2x at present with those in a 1.3°C cooler climate. For Tx3x, we also extend this analysis into the future by assessing the influence of a further 1.3°C of global warming from present. This is in line with the latest Emissions Gap Report from the United Nations Environment Programme, which shows that the world is on track for at least 2.6°C temperature rise given currently implemented policies ([UNEP, 2024](#)).

2 Hazard analysis

2.1 Australia - Trends in observations

2.1.1 Influence of modes of natural variability

The El-Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) are known to play a part in summer temperatures in this region (section 1.2). Therefore, we first investigate the effect of including these as additional covariates in the statistical model (section A1.3). ENSO is represented by the relative Niño3.4 index, averaged over the September-November period to capture the period immediately preceding the austral summer. The IOD is represented by the December average of the Dipole Mode Index (DMI) (see section A1.1 for further details).

We first fit a statistical model using different combinations of GMST and these indices as covariates, using the Akaike Information Criterion (AIC) to assess the goodness-of-fit relative to the complexity of each model. We find that including all three covariates or GMST and ENSO provide the best fit, but that GMST and IOD in combination is worse than GMST alone (Table A.1). As a result, the influence of the current (SON) ENSO conditions is considered in the observation-based analysis below, and the role of GMST is considered through the analysis.

In all observation-based datasets, compared to a neutral phase, the La Niña conditions preceding the summer season resulted in a decrease in the likelihood and intensity of such an event, with best estimates ranging from a factor of 0.55 to 0.8 in PR, meaning that La Niña reduced the likelihood of such extreme temperatures, and a reduction of 0.3 to 0.5°C in intensity for Tx3x (table 2.1). In four of the five datasets, the reduction due to La Niña conditions is significant at the 95% confidence level. It is worthy of note that the estimated influence of La Niña here is the net effect across the large study

region, while such conditions may also influence subregional scale differently. For instance, in Victoria, heatwaves are more likely during La Niña episodes ([Parker et al., 2014](#)).

Dataset	Event magnitude (°C)	Return period	Influence of GMST		Influence of ENSO	
			Probability ratio	Change in magnitude (°C)	Probability ratio	Change in magnitude (°C)
ERA5	39.47	13.4 (3.1 to 87.9)	13.8 (1.17 to inf)	1.50 (0.16 to 3.20)	0.55 (0.36 to 0.77)	-0.48 (-0.71 to -0.21)
MSWX	38.67	3.29 (1.22 to 25.1)	64.4 (0.50 to inf)	2.25 (-0.79 to +4.99)	0.79 (0.59 to 1.06)	-0.29 (-0.62 to +0.09)
MERRA2	40.57	10*	0.76 (0.33 to inf)	-0.41 (-1.42 to +4.17)	0.72 (0.62 to 0.96)	-0.5 (-0.69 to -0.11)
Berkeley	39.23	10*	40.9 (7.74 to inf)	2.14 (1.23 to 3.02)	0.68 (0.38 to 0.84)	-0.35 (-0.60 to -0.15)
AGCD	40.41	5.37	10.8 (3.97 to inf)	1.97 (1.24 to 3.06)	0.72 (0.56 to 0.89)	-0.36 (-0.57 to -0.14)

Table 2.1: Estimated return periods of Tx3x events over southern Australia in the 5 gridded observational and reanalysis datasets with coverage of the event, as well as change in probability and magnitude due to both GMST and ENSO with both covaries included in the model. Statistically significant trends are also highlighted in **bold font**. *return period and estimated event magnitude based on other datasets in which event is included.

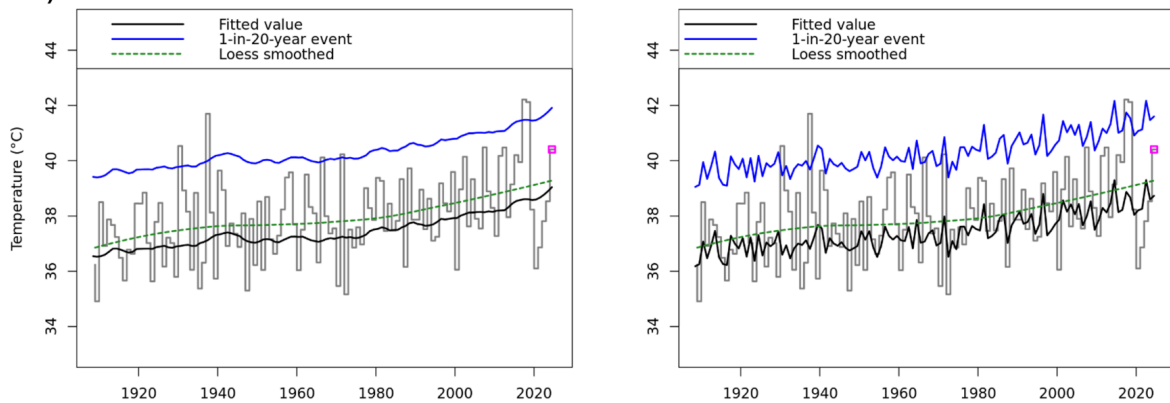
2.1.2 Influence of increasing global mean surface temperatures

In the second part of this analysis, we fit a statistical model using GMST as the only covariate, with no influence from natural variability assessed. Across the datasets using this model, an event such as is expected to occur approximately once every 5 years in the current climate (Table 2.2). This is more common than in the model incorporating ENSO as the cooling influence of La Niña is no longer explicitly accounted for.

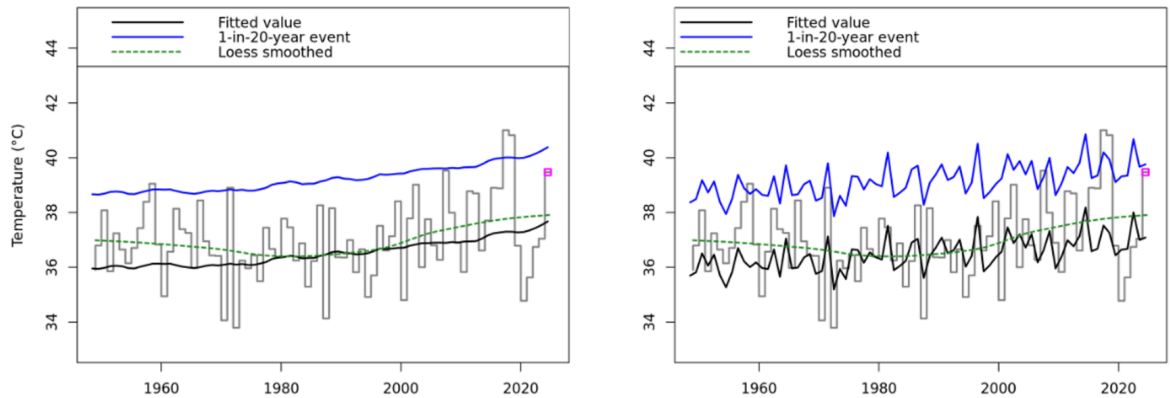
All datasets suggest an increasing trend in the likelihood and intensity of 3-day summer heatwaves in the study region with 1.3°C of global warming. Three of the five datasets (ERA5, Berkeley, AGCD) are statistically significant at the 95% confidence level. The two datasets that are not significant at this level are the shorter datasets, containing records back to only 1979, naturally resulting in wider confidence intervals from bootstrapping for a given rate of change and variability. In the case of MSWX, the best estimate an increase in likelihood by a factor of 22 (0.5 to inf) is broadly in line with the other estimates ranging from ~10-20, and the change in intensity of 2.2°C (-0.8 to +5.6°C) is in line with the best estimates in other datasets of 1.7 to 2.1°C.

However, the MERRA2 data suggest a far weaker increase with warming than the other datasets, with a best estimated probability ratio of 1.7 and change in intensity of 0.6°C . Figure 2.1 shows the time series of Tx3x in AGCD, ERA5 and MERRA2 (other datasets shown in Fig. A1), as well as the expectation from the fitted statistical model, and a loess smoothed average, highlighting the weaker trend in this dataset. Figure 2.2 shows return curves for the same three datasets, evaluated for the statistical model including both GMST and ENSO, for the preindustrial and current climates, and La Niña vs neutral conditions (other datasets shown in Fig. A2). In particular, the model fit to MERRA2 does not fit the data well in comparison to the other datasets, with substantial variation between the values of Tx3x and the approximated return periods even for commonly occurring events. This dataset is therefore discarded for the remainder of this analysis.

a) AGCD



b) ERA5



c) MERRA2

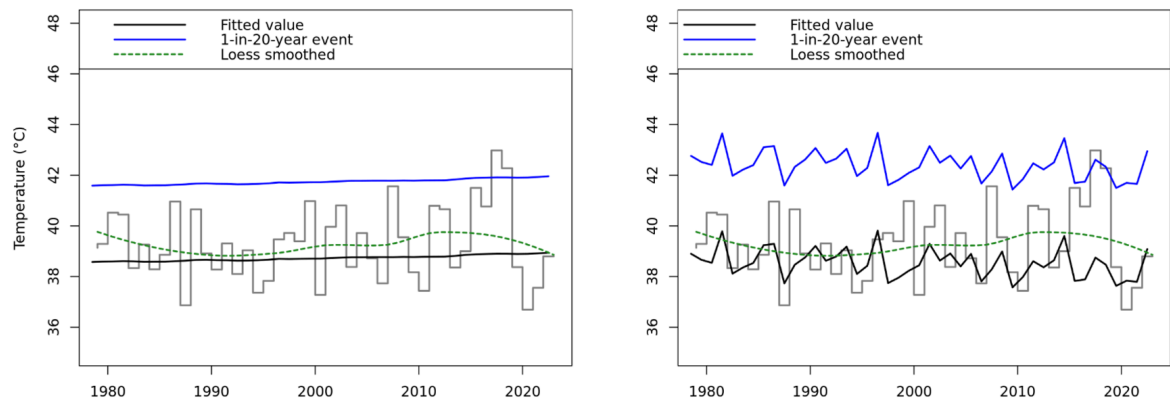
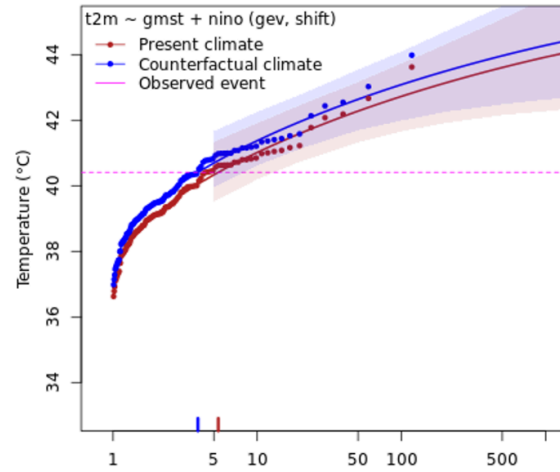
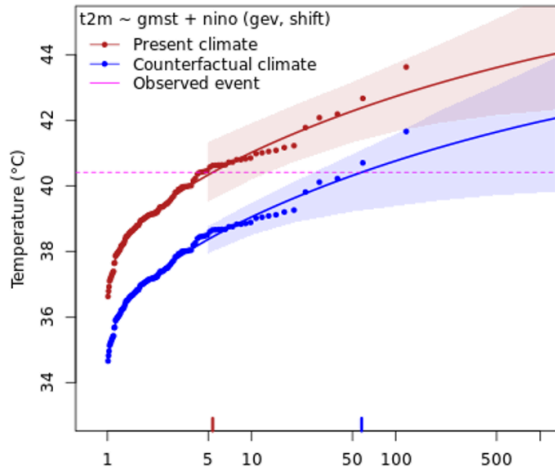
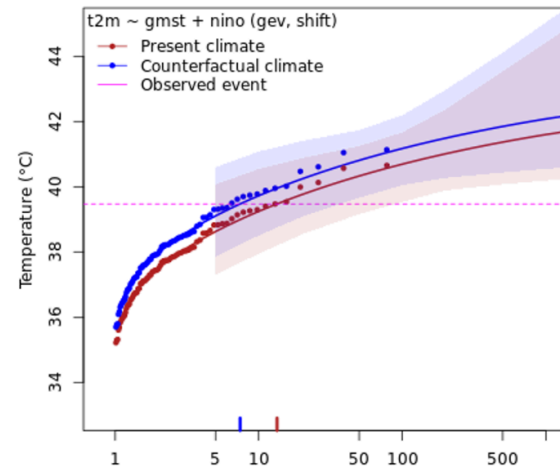
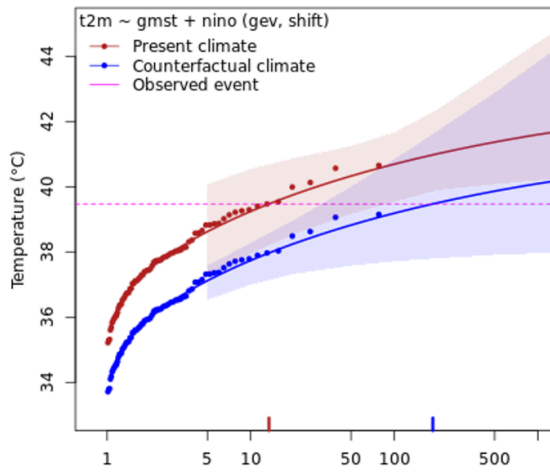


Figure 2.1: Time series of Tx3x in a) AGCD, b) ERA5 and c) MERRA2. The modelled influence of GMST (left) and GMST & ENSO on the expected value (20- year return period value) is shown with the black line (blue line), while the loess smoothed trend is shown with the green dashed line. The purple box shows the magnitude of the observed event in ERA5 and AGCD.

a) AGCD



b) ERA5



c) MERRA2

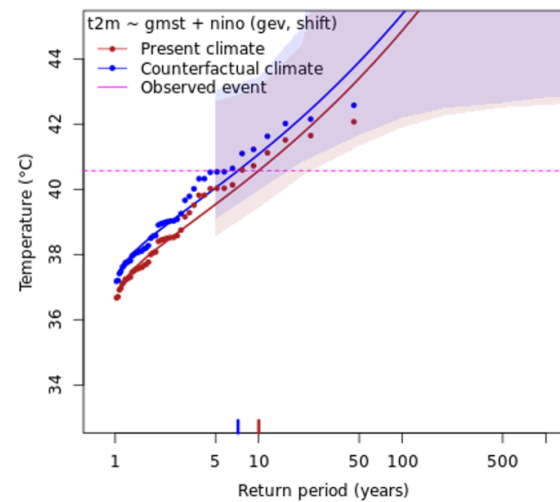
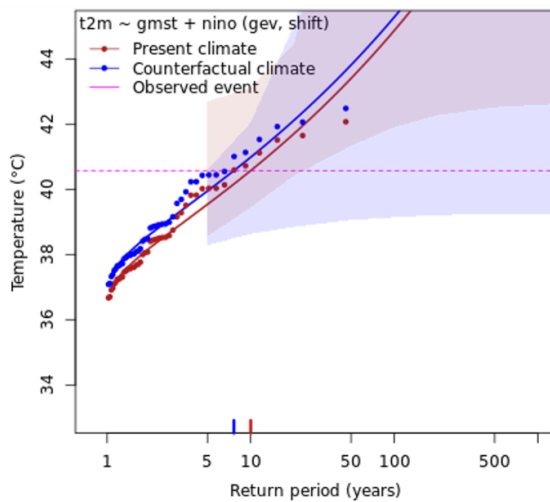


Figure 2.2: Statistical fits to T_{x3x} , in a) AGCD, b) ERA5, and c) MERRA2. The influence of the current GMST (left) and ENSO (right) conditions is shown with the red vs blue probability curves,

showing the present vs preindustrial warming levels (left), and La Niña vs Neutral conditions (right). The magnitude of the event is highlighted with a horizontal purple line.

Dataset	Event magnitude (°C)	Return period	Influence of GMST	
			Probability ratio	Change in magnitude (°C)
ERA5	39.47	5.86 (2.19 to 48.7)	16.8 (1.44 to inf)	1.67 (0.26 to 2.93)
MSWX	38.67	2.70 (1.14 to 18.6)	22.4 (0.48 to inf)	2.15 (-0.77 to +5.57)
MERRA2	40.75	5*	1.70 (0.16 to inf)	0.55 (-2.12 to +4.49)
Berkeley	38.92	5*	19.8 (6.11 to 3470)	2.07 (1.13 to 2.92)
AGCD	40.41	3.86 (1.86 to 8.06)	9.82 (4.17 to 383)	1.94 (1.16 to 3.05)

Table 2.2: Estimated return periods of Tx3x events over southern Australia in the 5 gridded observational and reanalysis datasets with coverage of the event, as well as change in probability and magnitude due to GMST with GMST as the sole covariate. Statistically significant trends are also highlighted in **bold** font. *return period and estimated event magnitude based on other datasets in which event is included.

Overall, there is a clear increasing trend in observations and reanalyses with global warming. This is clear both at the local scale (Fig. 1.3) and the regional scale (Table 2.2). Over the study region, the observed increase in the likelihood of Tx3x events similar to summer 2026 is a factor of approximately 10 to 20, with a corresponding increase in the intensity of 1-in-5-year events of roughly 1.7°C to 2.2°C (or about 1.5 times the average global warming rate).

2.2 New Zealand - Trends in observations

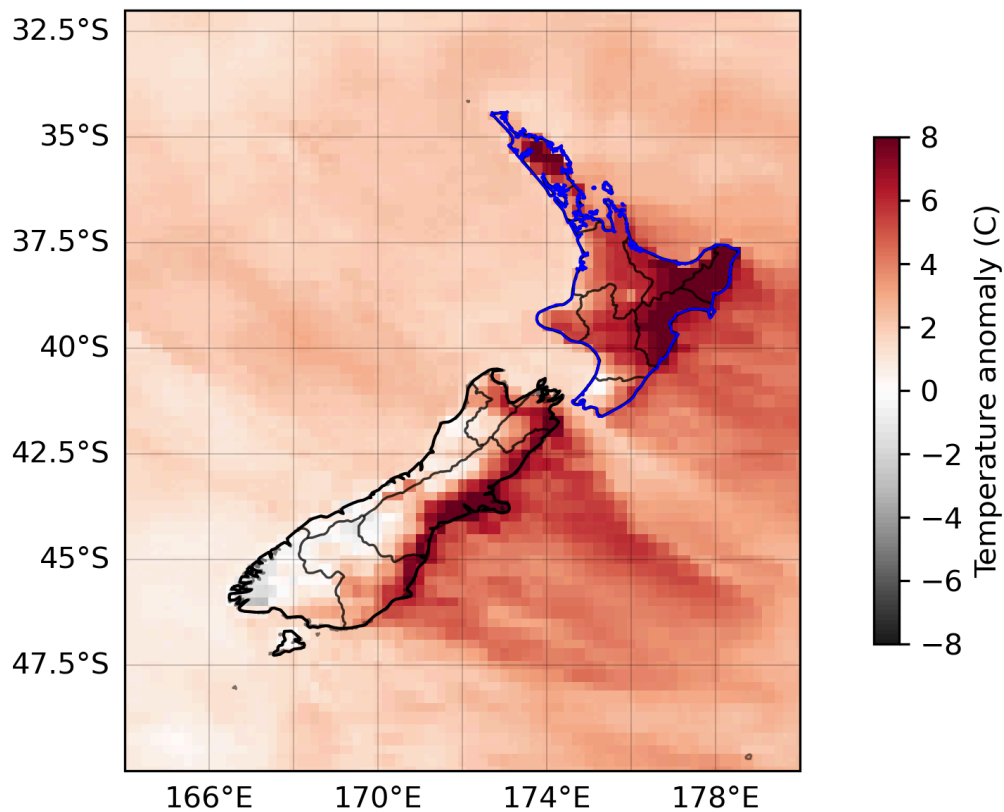


Figure 2.3: Anomalies of 2-day daily maximum temperatures from 10-11th January 2026 over New Zealand with respect to mean summer (December-February) daily maximum temperatures over the 1991-2020 climatological period. The study region is shown in blue. Data: MSWX.

As described in section 1, strong westerlies from Australia resulted in a 2-day spike in summer temperatures over New Zealand, particularly North Island and the eastern coast of South Island (Fig. 2.3). Assessing the 2-day maximum temperatures over North Island using the same statistical model as section 2.1.2, using GMST as the sole covariate, we found that events such as this are expected to occur approximately every 5 years in the current climate.

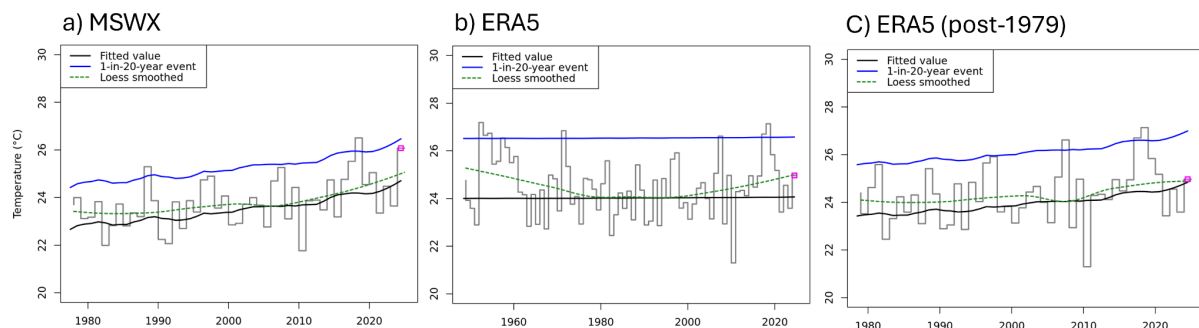


Figure 2.4: Time series of T_{x2x} in a) MSWX, b) ERA5 and c) ERA5 post-1979. The modelled influence of GMST on the expected value (20- year return period value) is shown with the black line (blue line), while the loess smoothed trend is shown with the green dashed line. The purple box shows the magnitude of the observed event.

MSWX and ERA5 both suggest increasing trends in the Tx2x index (Table 2.3). However, MSWX shows a strong and statistically significant increasing trend with a change in likelihood of such an event by at least a factor of 6 due to warming of 1.3°C, and an intensity increase of 2.3°C (0.9 to 3.6°C). ERA5 from 1950 shows almost no change. Figure 2.4 shows the time series of Tx2x, the expectation from the fitted statistical model, and the loess smoothed trend. This shows that ERA5 displays a substantial warm period of Tx2x events from the early 1950s to early 1960s, resulting in a declining smoothed trend through the 1960s and 1970s. Without further information we can not judge whether the high temperatures are a data artifact e.g. due to sparse data in the early years or a real signal. Across the whole record, this results in no significant change due to global warming. Limiting the ERA5 data to 1979 onwards for consistency with MSWX, we see a strong and significant trend in this dataset (Fig. 2.4c, Table 2.3). Overall, it is clear that global warming has resulted in a rapidly rising rate and intensity of Tx2x events in recent decades, though quantifying this effect and disentangling other drivers of change requires further analysis.

Dataset	Event magnitude	Return period	Influence of GMST	
			Probability ratio	Change in magnitude (°C)
ERA5	24.97	2.95 (1.79 to 8.02)	1.08 (0.34 to 2.73)	0.09 (-1.09 to +1.04)
ERA5 (post-1979)	24.97	1.77 (1.16 to 3.91)	8.36 (1.41 to inf)	1.81 (0.26 to 3.46)
MSWX	26.07	8.49 (2.49 to 133)	inf (5.96 to inf)	2.32 (0.91 to 3.59)

Table 2.3: Estimated return periods of Tx2x events over North island in the 2 gridded observational and reanalysis datasets with coverage of the event, as well as change in probability and magnitude due to GMST with GMST as the sole covariate. Statistically significant trends are also highlighted in **bold font**.

2.3 Evaluation of climate models

In the subsections below we show the results of the model evaluation for each location. The climate models are evaluated against the observations in their ability to capture:

1. Seasonal cycles: For this, we qualitatively compare the seasonal cycles based on model outputs against observations-based cycles. We discard the models that exhibit ill-defined peaks in their seasonal cycles.
2. Spatial patterns: Models that do not match the observations in terms of the large-scale summer temperature patterns are excluded.
3. Parameters of the fitted statistical models. We discard the model if the model and observation parameters ranges do not overlap.

The models are labelled as ‘good’, ‘reasonable’, or ‘bad’ based on their performances in terms of the three criteria discussed above. A model is given an overall rating of ‘good’ if it is rated ‘good’ for all three characteristics. If there is at least one ‘reasonable’, then its overall rating will be ‘reasonable’ and ‘bad’ if there is at least one ‘bad’. For each framing or model setup we also use models that only just pass the evaluation tests if we only have five models or less for that framing that perform well. Overall, 8 of the 19 CMIP6 models and 10 of the 14 CORDEX-AUS models were labelled ‘good’ and therefore retained in this study. Tables of the model evaluation results can be found in Appendix A2.

2.4 Synthesis of results

For the event definitions described above we evaluate the influence of anthropogenic climate change on the events by calculating the probability ratio as well as the change in intensity using observations and climate models. Models which do not pass the evaluation described above are excluded from the analysis. The aim is to synthesise results from models that pass the evaluation along with the observations-based products, to give an overarching attribution statement.

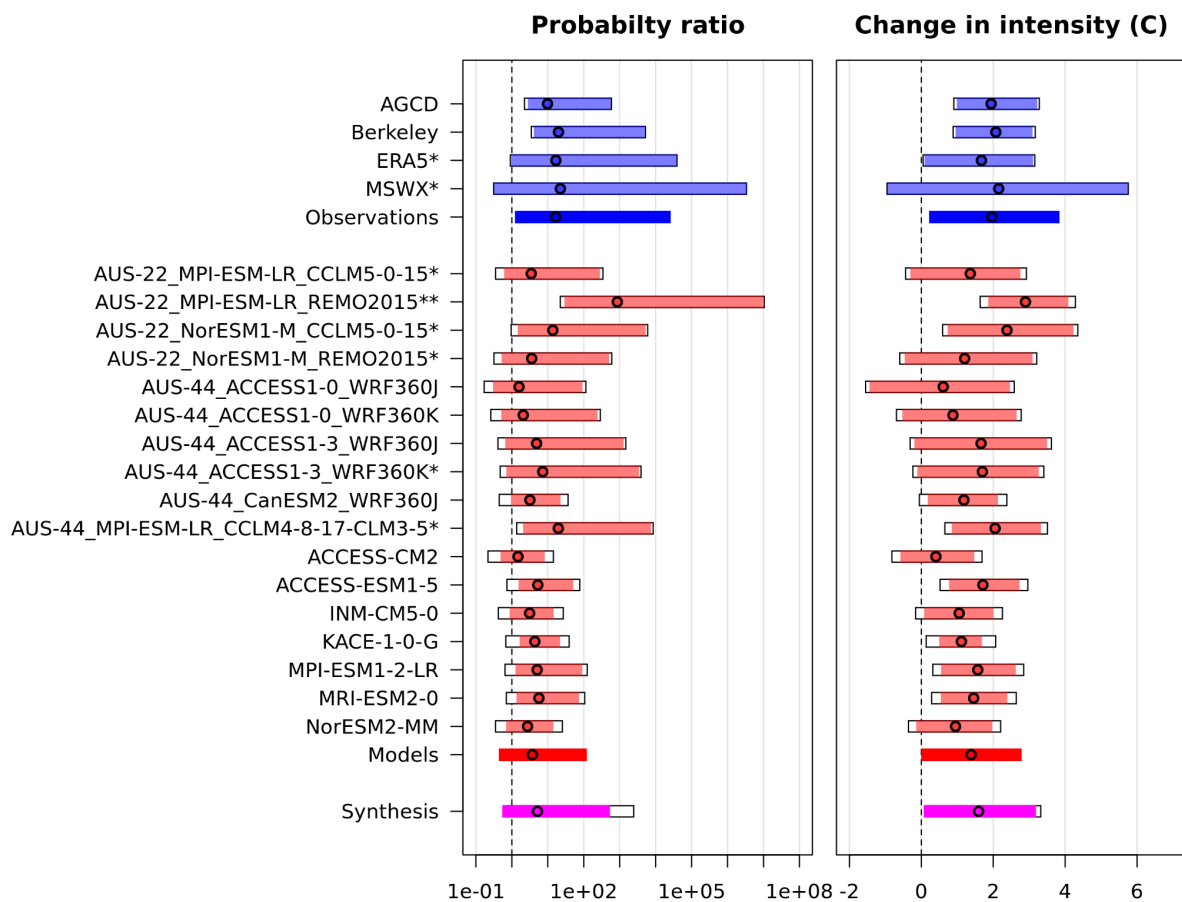


Figure 2.5: Synthesis of change in (a) probability and (b) intensity of a 1-in-5-year $Tx3x$ in southern Australia when comparing the 2025 climate and a 1.3°C cooler climate representing the preindustrial past. The synthesised observational estimate Probability ratios with an infinite upper bound replaced are flagged with “*”; probability ratios with infinite best estimate and upper bounds replaced are flagged with “**”.

Figures 2.5 and 2.6 show the changes in probability and intensity for the observations (blue) and models (red). Before combining them into a synthesised assessment, first, a representation error is

added (in quadrature) to the observations, to account for the difference between observations-based datasets that cannot be explained by natural variability. This is shown in these figures as white boxes around the light blue bars. The dark blue bar shows the average over the observation-based products. Next, a term to account for intermodel spread is added (in quadrature) to the natural variability of the models. This is shown in the figures as white boxes around the light red bars. The dark red bar shows the model average, consisting of a weighted mean using the (uncorrelated) uncertainties due to natural variability plus the term representing intermodel spread (i.e., the inverse square of the white bars).

Observation-based products and models are combined into a single result in two ways. Firstly, we neglect common model uncertainties beyond the intermodel spread that is depicted by the model average, and compute the weighted average of models (dark red bar) and observations (dark blue bar): this is indicated by the magenta bar. As, due to common model uncertainties, model uncertainty can be larger than the intermodel spread, secondly, we also show the more conservative estimate of an unweighted, direct average of observations (dark blue bar) and models (dark red bar) contributing 50% each, indicated by the white box around the magenta bar in the synthesis figures.

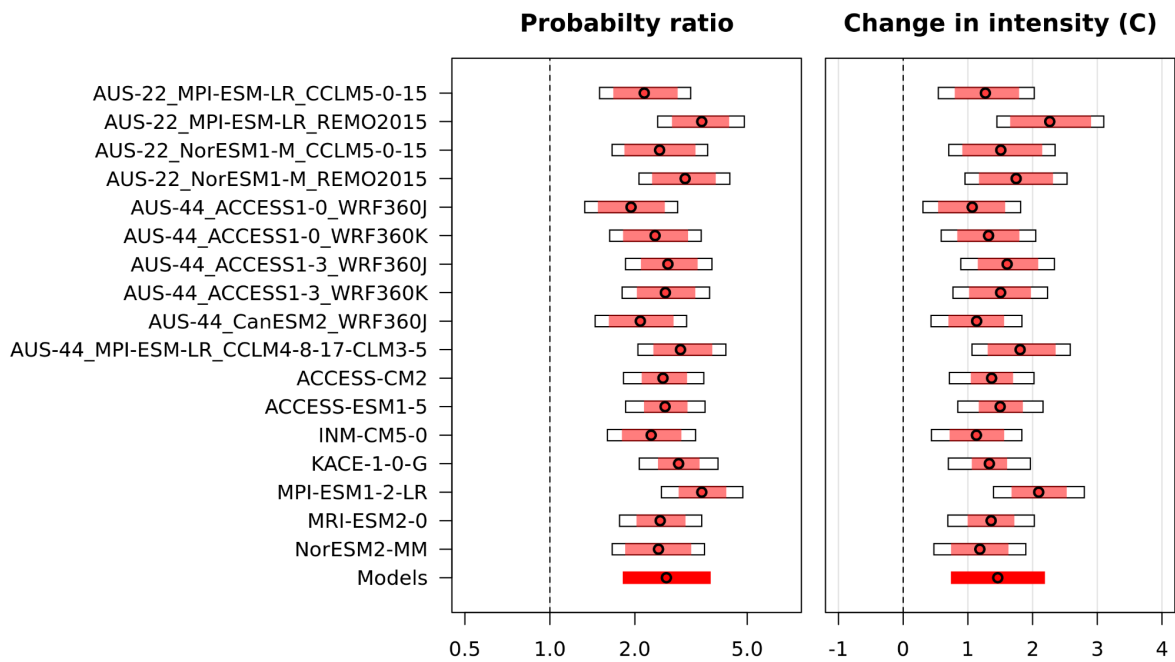


Figure 2.6: Synthesis of change in (a) probability and (b) intensity of a 1-in-5-year $Tx3x$ in southern Australia when comparing the 2025/2026 climate and a 1.3°C warmer climate representing the end of the century under current policies.

Data	Attributable influence of GMST		
		Probability ratio (95% CI)	Intensity change (°C) (95% CI)
Observations	Past-Present	16.4 (1.82 to 17500)	1.96 (0.39 to 3.67)
Models		3.73 (0.65 to 81.6)	1.39 (0.17 to 2.62)
Synthesis		5.14 (0.81 to 358)	1.59 (0.24 to 3.01)
Models only	Present-Future	2.59 (1.91 to 3.53)	1.46 (0.84 to 2.09)

Table 6.1: Summary of results for probability ratio and change in intensity for Tx3x, presented in Figs. 2.5 & 2.6: changes due to GMST include past-present changes and present-future changes. Statistically significant changes are also highlighted in **bold font**.

The synthesised results show clearly that 3-day heat events in the study region in Australia are increasing in both likelihood and intensity with global warming. Observational and reanalysis datasets estimate that the likelihood of such an event has increased by a factor of approximately 16 (1.8 to 17500), or equivalently that the intensity of a 1-in-5-year event has increased by 2.0°C (0.4 to 3.7°C). The model synthesis gives slightly lower estimates, with the likelihood of such an event increased by a factor of approximately 3.7 (0.7 to 82), or equivalently that the intensity of a 1-in-5-year event has increased by 1.4°C (0.2 to 2.6°C). This is likely an underestimate, a characteristic we see more often for heat, although this is not as pronounced as for instance in western Europe.

Synthesising the estimates from observations and models, we conclude that this event has increased in likelihood by a factor of approximately 5.1 (0.8 to 360), or equivalently that the intensity of a 1-in-5-year event has increased by 1.6°C (0.2 to 3.0°C). With an additional 1.3°C of warming from present, such events will be an additional 2.6 (1.9 to 3.5) times more likely, and equivalently 1.5°C (0.8 to 2.1°C) hotter.

2.5 Conclusions

The main result of this hazard analysis is that 3-day heat extremes in southern Australia like the one that occurred on 7-9th January 2026 have become much more likely and intense due to warming of the atmosphere by 1.3°C since the preindustrial period. We also found that, given that another 1.3°C of warming expected with current climate policies, such events will become yet more likely and intense.

This event also occurred during a La Niña episode. This analysis found that this mode of natural variability reduced the likelihood of reaching such temperatures by a factor of approximately ~0.55-0.8 compared to a neutral phase of ENSO. Equivalently, it reduced the intensity of such an event by 0.3 to 0.5°C. It is important to note that the estimated influence of La Niña is an average over the large study region, with subregions such as the far southeast likely influenced differently.

Finally, in the North Island of New Zealand, which was affected by the same heat event on subsequent days, reanalysis datasets show a very strong increasing trend in such extremes since the 1980s. Further work using in-situ observations is required to validate and disentangle the drivers of a warm period of heat extremes in the 1950s-1960s shown in ERA5, but it remains clear from both strong recent trends in the satellite era, other literature, and simple physics that such extremes are becoming much more likely and intense as the world warms.

3 Vulnerability and exposure

The January 2026 heatwave in Australia affected large parts of the continent from early January, with prolonged extreme temperatures across southern and eastern states, including South Australia, New South Wales, Victoria, and parts of Queensland. The event was characterized by multi-day maxima 10-15 degrees C above seasonal averages (exceeding 49°C in some locations) and high overnight minimum temperatures (low to mid-20s), limiting nocturnal relief and increasing cumulative heat stress ([Lam, 2026](#); [Philips, 2026](#)). The high temperatures have also caused a spike in ozone levels, leading to “poor” air quality levels, particularly in Sydney ([NSW Government, 2026](#)), representing a compounding hazard for respiratory and cardiovascular health.

Periods of extreme heat are Australia’s deadliest natural hazard, with well-documented impacts including excess mortality, heat-related illness, reduced labor productivity, and exacerbation of mental health conditions ([Kernaghan, 2024](#); [Coates et al., 2022](#); [Oppermann et al., 2017](#)). National evidence shows that heat-related mortality and morbidity risks often peak on the day of exposure or shortly after, with the strongest associations documented in temperate and subtropical urban areas, including Melbourne, Sydney, and Adelaide ([Bhatta et al., 2023](#)). However, health impacts in rural, remote, and socioeconomically disadvantaged populations remain under-assessed. While health impacts are the most extensively studied, heatwaves disrupt electricity and water supply, strain health services, affect transport and education through service interruptions, reduce safe working hours and livelihoods, including an estimated annual productivity loss of A\$6.9 billion (≈4.6 billion US dollar), and increase demand for cooling and emergency shelter ([Oppermann et al., 2017](#); [Amoatey et al., 2025](#)).

Despite comparable temperatures and elevated fire weather risk, the impacts associated with the January 2026 heatwave do not seem to directly mirror those of earlier, highly deadly extreme events as experienced in 2009 and 2019-2020. Differences in antecedent drought conditions and advances in fire danger rating systems and preparedness likely moderate fire outcomes, despite the compounding extreme heat, dry fuels, and concurrent fire activity.

The following subsections examine the key drivers of heat risk in this context, focusing on patterns of vulnerability, exposure, and coping capacity that shape both impacts and response options.

3.1 Sociodemographics

The heatwave covered a large area of Australia, including urban areas with high populations, but also rural regions with very low population densities. These densely populated urban areas experience higher temperatures, which in some cases systematically exceed official station measurements ([Pfautsch et al., 2025](#)). Australia is highly urbanised, and this is an ongoing trend with population growth rates in urban areas surpassing those in rural areas ([James et al., 2021](#)). The recent study by Amoatey et al. ([2025a](#)) investigated how vulnerability to heatwaves varies spatially and temporally across Australia and found that social isolation, low education and low income were factors that increased vulnerability. Earlier analysis by Toloo et al. ([2014](#)) in the Brisbane area showed that socioeconomically disadvantaged groups were more vulnerable to heat impacts, particularly elderly citizens. Amoatey et al. ([2025b](#)) report on the larger vulnerability of Indigenous groups in Australia to extreme heat based on statistical analysis of earlier heatwaves. Hall & Crosby ([2020](#)) specifically

report on the vulnerability of Aboriginal and Torres Strait Islander Peoples living in remote areas, thereby illustrating that vulnerability can also be high outside of the urban areas with their well-known urban heat island effects. Vulnerability of Indigenous Peoples to extreme Australian heatwaves is further described in section 4.1.2.

Unhoused people are particularly vulnerable because they may not have access to shelters to escape the heat and may have limited access to clean drinking water ([English et al., 2025](#)). Compounding factors may include mental illness, medication and substance use disorder, which can limit self-efficacy during heatwaves (e.g., [English et al., 2022](#)). Interviews with unhoused people in Adelaide during previous heatwaves revealed that the vast majority of the interviewees were experiencing heat stress symptoms ([Every et al., 2021](#)). Some initiatives specifically target this vulnerable group, e.g. the mobile cooling hubs in Sydney where water and cooling fans are available to citizens ([City of Sydney](#), accessed 17 Jan 2026). For suburban areas, an increase in homelessness is reported over the period 2001-2021, related to a lack of affordable housing ([Batterham et al., 2024](#)). Beyond the absolute changes in the number of homeless people, there are spatial trends, with more homelessness increasing in particular in urban areas with expensive housing ([Batterham et al., 2022](#)). The Organisation for Economic Co-operation and Development ([OECD, 2024](#)) reports that homelessness in Australia is 0.48%, somewhat higher than for most other OECD countries (which can be partly attributed to inconsistent definitions used across countries), and that a large fraction (>40%) of the unhoused people are migrants, that often experience additional challenges (see section 4.1.2 on structural inequality aspects related to vulnerability).

3.1.1 Health

In Australia, extreme heat is known to be the deadliest natural hazard, having been associated with over 5000 deaths between 1844 and 2010, more than the deaths associated with all other natural hazards combined ([Coates et al., 2022](#); [Coates et al., 2014](#)). The risk of heat-related mortality is shown to be higher in people with mental or behavioral disorders, cardiovascular diseases, diabetes, respiratory diseases, older age, as well as social isolation ([Amoatey et al., 2025](#); [Coates et al., 2022](#)). In a study looking at heatwave mortality across communities in Australia, large differences were found. Communities with a higher proportions of elderly residents, gender imbalance, individuals needing assistance, and lower income or education, especially in Queensland and New South Wales, had higher mortality ([Xu et al., 2025](#)). These differences also imply the need for targeted public health interventions ([Xu et al., 2025](#)).

Extreme heat also impacts otherwise healthy males aged 15 to 35 years as they make up a large proportion of the outdoor workforce highly exposed to extreme heat, especially in construction jobs. One study shows an increase in work-related injuries and illnesses during moderate and high-severity heatwaves in three Australian cities ([Varghese et al., 2019](#)), while another estimates a 5-29 % risk of occupational injuries and illnesses is linked to heatwaves ([Fatima et al. 2014](#)).

News reports on the January 2026 heatwave echo this, including reports of a 25% increase in heat-related presentations at the Royal Melbourne Hospital, and of an increase in emergency presentations for the elderly and people with mental health issues ([ABC, 2026a](#), [ABC, 2026b](#)).

3.1.2 Structural inequality

Evidence from Australia indicates that foreign-born populations, particularly migrants and refugees from culturally and linguistically diverse backgrounds, may experience elevated heat risk due to intersecting factors such as language barriers, socioeconomic disadvantage, and culturally mediated behaviours ([Hansen et al., 2014](#)). Qualitative findings for Sydney, Melbourne and Adelaide, show that limited English proficiency and low literacy can constrain access to heat-health warnings and public advice, while unfamiliarity with Australian heat (often perceived as drier, more intense, and with limited nighttime cooling) undermines assumptions that people from warmer climates are inherently acclimatised ([Hansen et al., 2014](#)). Cultural norms related to clothing, food preparation, fluid intake, religious practices, and daily routines can further increase exposure when they limit hydration, cooling behaviours, or the use of air-conditioned environments. These factors interact strongly with social class and housing conditions, as newly arrived migrants and low-income households are more likely to reside in poorly insulated rental housing without air conditioning and to limit cooling due to high electricity costs. While strong community and family networks can be protective, social isolation (particularly among older migrants and those with limited language ability) emerged as a key vulnerability factor. The study demonstrates that heat vulnerability is shaped by the interaction of cultural practices, socioeconomic position, housing quality, and access to information, rather than culture alone, and shows the importance of culturally appropriate heat-health communication and targeted outreach.

Similar structural drivers of heat vulnerability have been documented for Aboriginal and Torres Strait Islander populations, particularly in remote and regional Australia. Quilty et al. ([2022](#)) describe how extreme heat intersects with poor housing quality, energy insecurity, and high burdens of chronic disease, creating conditions in which dwellings can become dangerously hot and cooling options unreliable or unaffordable. Prepaid electricity systems, frequent power disconnections, and inadequate housing design further constrain the ability to maintain safe indoor temperatures.

3.2 Urban built environment

The built environment in affected cities such as Adelaide, Melbourne, Sydney, and Hobart (Tasmania) disproportionately amplifies heat exposure. Urban Heat Island (UHI) effects increase maximum temperatures by up to 13°C in Sydney, 5.7°C in Hobart, 4°C in Melbourne, and 1.3°C in Adelaide compared to surrounding areas ([Yenetti et al., 2022](#)). UHI effect intensity is influenced by urban design, land cover, and proximity to cooling green and blue spaces ([Fatima et al., 2025](#)). The Australian observatory ([2025](#)) notes that Western Sydney and Melbourne's outer suburbs, such as Brimbank, face particularly high UHI effects due to low tree cover, low precipitation, and distance from the ocean. High UHI effect microclimates are also observed in central areas, including Carlton and Fitzroy in Melbourne and Woolloomooloo and Rushcutters Bay in Sydney.

A case study from Jordan Springs in Western Sydney highlights the role of urban design in heat exposure. Developer guidelines promote narrow spacing between houses (1.8 m side and 6 m rear), wide streets, and low building heights, creating “heat canyons” where shade is minimal and dark, impermeable surfaces dominate ([Haynes, Calgaro & Dominey-Howes, 2021](#)). Temperature differences between surfaces can reach 20–30°C (see Figure 3.1 below).



Figure 3.1: Street layouts in Jordan Springs, Western Sydney, and Aerial Thermal imagery measuring surface temperature in °C ([Haynes, Calgaro & Dominey-Howes, 2021](#)).

High UHI often overlaps with socioeconomic vulnerability ([Amoatey et al., 2025b](#), see Figure 3.2, for detail). Those in lower-income areas experience higher indoor temperatures due to poor building materials, limited insulation, single glazing, and older building stock, exposing them to disproportionate UHI at a city level and at an individual level ([Daly et al., 2021](#), [Baeza-Rajagopalan & Andamon, 2020](#)). A survey of social housing in Western Sydney during the 2019 heatwave found indoor temperatures exceeding safe levels for prolonged periods, up to 114 continuous hours above 32°C and 997 hours above 26°C ([Haddad et al., 2022](#)). Residents often had only pedestal fans for cooling, which in hot, dry conditions can exacerbate health risks, though combining fans with skin wetting remains effective ([Chaseling et al., 2024](#)). A thermally safe home is a basic human right, yet social housing often struggles to provide adequate comfort during the frequent hot and extreme summer days experienced across the continent ([Pfautsch et al., 2024](#)).

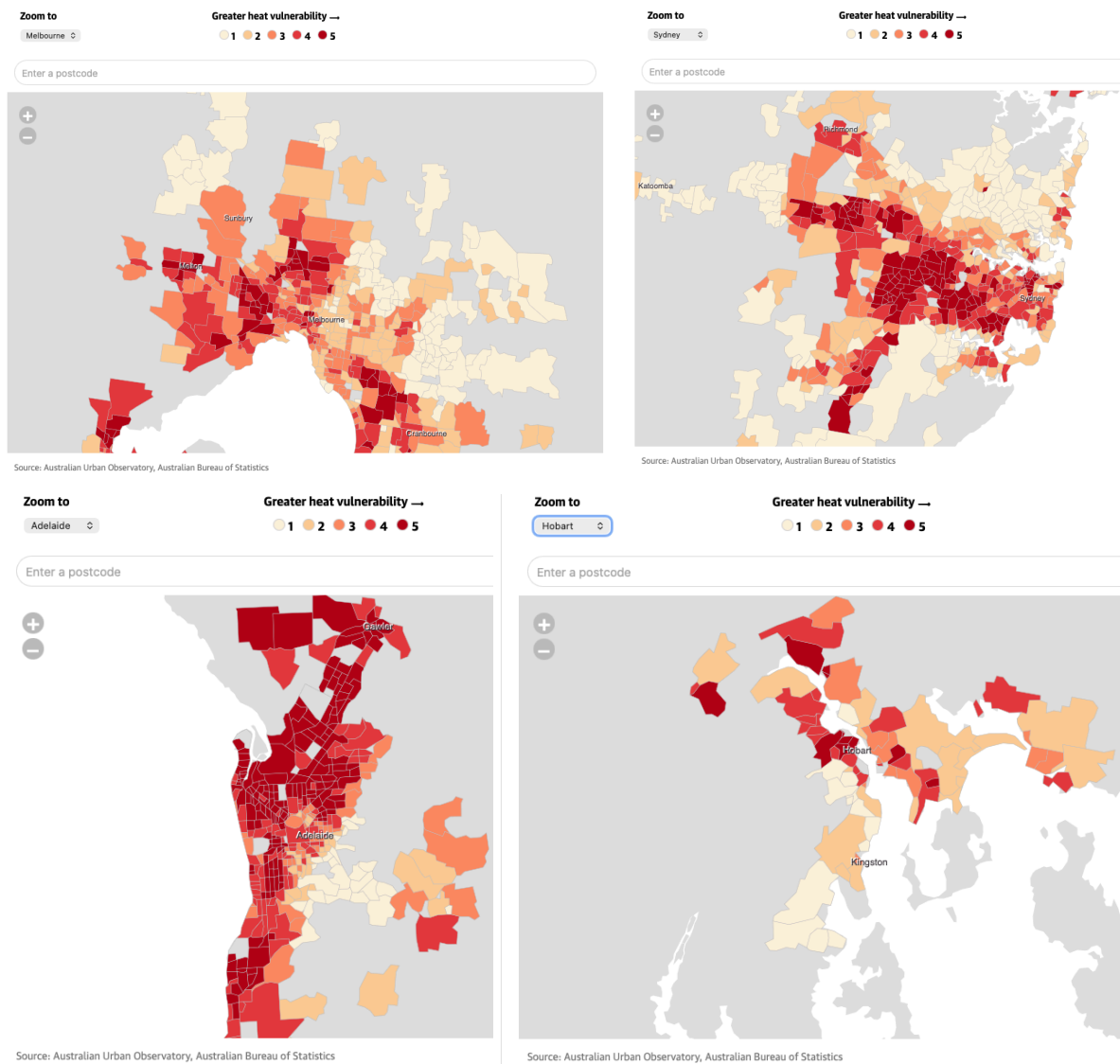


Figure 3.2: Heat vulnerability mapping from RMIT combining temperature data, susceptible populations, built environment, green space, and socioeconomic factors ([The Guardian, 2025](#)). Top left to bottom right: Melbourne, Sydney, Adelaide, Hobart.

Despite widespread UHI effects, urban adaptation in Australia has progressed. Comparative analyses of Sydney, Brisbane, Adelaide, Perth, Darwin, and Hobart show that vulnerability clusters linked to built environment and socioeconomic factors have decreased between 2011 and 2021 due to adaptation measures ([Amoatey et al., 2025b](#)). Interventions include vegetated infrastructure, shading, reflective surfaces, thermally efficient materials, misting systems, and passive ventilation, which together reduce peak temperatures and energy consumption across various cities ([Adnan et al., 2022](#)). Evidence from Melbourne suggests that combining vegetation with high-albedo surfaces could lower average air temperatures by an additional 2.4°C ([Herath et al., 2023](#)). Even so, access to urban cooling infrastructure and green space remains uneven, with cooler, greener areas often concentrated in higher socioeconomic neighborhoods, limiting the benefits of these interventions for vulnerable populations ([Balany et al., 2022](#); [Norton et al., 2015](#); [Santamouris & Osmond, 2020](#)). Developers often find heat-sensitive designs unfeasible due to existing street layouts and fragmented land ownership

([Boletter et al., 2025](#)) and environmental protection limits land clearing, prompting higher-density development on smaller lots, which can intensify UHI effects ([Haynes, Calgaro & Dominey-Howes, 2021](#)). Additionally, heatwaves cause tree mortality, reducing shade and cooling options for subsequent heat events ([Sanusi & Livesley, 2020](#)). Further, reliance on air conditioning as adaptation increases local UHI effects due to excess heat and intensifies energy demands ([Boletter et al., 2025](#)). Australian cities' strategic plans for heat reduction from Adelaide, Canberra, Melbourne, and Sydney address UHI effects in detail, while Brisbane, Darwin, and Perth reference it, and Hobart made no mention as of 2019 ([Elgendawy & Elvis, 2019](#)).

3.3 Critical systems and services

Systems and services like energy, transport, health, water, and urban infrastructure play a central role in shaping population exposure, vulnerability, and coping capacity during extreme heat events. The January 2026 heatwave imposed substantial stress on some of these systems across southeastern Australia. Electricity networks experienced localized failures, with around 35,000 customers in Victoria losing power at the peak of the heat ([Stock, 2026](#)). Overall, record daytime electricity demand has reportedly been met more smoothly than in past heatwaves, with abundant solar generation (providing over 60% of midday power and significantly more when combined with wind and hydro) keeping prices stable ([Mercer, 2026](#)). This is a stark contrast to earlier years when primarily coal and gas plants struggled to meet demand ([Mercer, 2026](#)).

Transport services were also disrupted, with cancellations limiting mobility and access to essential services ([Stock, 2026](#)). Further, during the event, hospitals in Melbourne, Sydney, and Port Augusta reported marked increases in heat-related presentations ([ABC, 2026](#)), consistent with literature showing extreme heat drives higher hospital admissions, emergency department presentation, ambulance call-outs, healthcare costs, and heat-related deaths ([Borg et al., 2023](#); [Manson et al., 2022](#); [Tong et al., 2021](#)).

3.4 Heat risk management

3.4.1 Governance

In Australia, heat risk management is governed across levels, with a National Heatwave Warning Framework developed in 2022 to support a systematic approach to heat health and warnings across states and territories ([Bureau of Meteorology, 2022](#)). It is a decentralized, state-led heat management supported by strong national coordination ([UNDRR, 2025](#)). The Bureau of Meteorology (BoM) provides warnings of extreme heat along with pre-agreed action statements developed by the National Heatwave Working Group (NHWG) that can guide state and local actions ([Bureau of Meteorology, 2022](#)). States and territories develop their own heatwave plans, and coordinate with local governments and stakeholders. Policies and plans such as worker safety laws also support risk management.

For the January 2026 heatwave, government officials across Australia, ranging from federal leaders to state premiers, emergency service chiefs, fire authorities, and health officials warned about the heatwave risks, held multiple briefings, and reiterated the deadly risks posed by the extreme heat with

recommendations on precautions to take ([9News, 2026](#); [RNZ, 2026](#)). For example, in New South Wales, the Premier emphasized the threat to lives and urged residents to stay vigilant and hydrated. Similar warnings came from South Australia's Premier and State Emergency Service Chief of Staff, as well as Victoria's Deputy Chief Health Officer.

3.4.2 Policies and plans

Heat risk governance in Australia is underpinned by formalized heat action planning and occupational safety frameworks, which shaped baseline preparedness ahead of the January 2026 heatwave. In Victoria, Emergency Management Victoria's extreme heat sub-plan (SEMP) provides a coordinated all-hazards framework for forecasting, warnings, health system readiness, and community protection, with three-year review cycles to guide continuous improvements ([EMV, 2025](#)). Sydney's Heat Smart City Plan, in particular, is a unique example of an intervention that brings together government agencies, industry, and utilities to safeguard the metro area from both the immediate challenges of extreme heat and to build long-term resilience. It involves the implementation of 40 actions that range from assessment of heat risks, coordination within the city and with communities, ensuring safe housing, safe working conditions, considering heat in urban planning, private sector support to heat adaptation and many more ([Greater Sydney Heat Smart City Plan, 2025](#)).

Analytical frameworks such as the Post-Event Review Capability (PERC) are also being adopted to strengthen institutional learning and urban heat governance ([Johnstone, 2025](#)). Worker safety legislation and guidance are critical components of heat risk management, as heatwaves are associated with increased occupational injuries, productivity losses, and economic costs ([Hunt et al., 2023](#)). Effective workplace interventions - hydration, shade, cooling, adjusted work hours, and heat stress education - are well established and shown to reduce morbidity and costs ([Borg et al., 2023](#); [Hunt et al., 2023](#)).

3.4.3 Early Warning System

Australia has an advanced heat early warning system, developed in response to the severe health impacts of past extreme heat events. Heat-health warning systems were first introduced at the state level in South Australia and Victoria following the 2009 extreme heatwave, which resulted in significant excess mortality and health system strain ([Nitschke et al., 2016](#)). In 2014, the Bureau of Meteorology (BoM) introduced a national 7-day heatwave severity forecast service, which became the national heatwave warning service in late 2022.

BoM's heatwave service operates within the National Heatwave Warning Framework, launched in 2022 to support a systematic approach to heat health and warnings across states and territories ([Bureau of Meteorology, 2022](#)). Under this framework, BoM issues multi-tiered, colour-coded heatwave warnings using a three-level structure: Advice, Watch and Act, and Emergency Warning. Warnings are spatially explicit and communicated through maps showing heatwave severity, accompanied by information on expected minimum and maximum temperatures, the timing of peak conditions, and a list of affected towns and communities within each warning area ([HealthVic, n.d.](#)). The heatwave forecast maps present the final day of each rolling three-day assessment (today and tomorrow) and a five-day outlook. Heatwaves are defined through the Excess Heat Factor (EHF), which accounts for both long-term climatology and short-term acclimatisation based on preceding temperatures ([Loridan et al., 2016](#); [Bettio et al., 2019](#); [Nairn & Fawcett et al., 2014](#)). Multiple studies

demonstrate that EHF is strongly associated with increased health service demand and heat-related mortality, supporting its suitability for triggering heatwave response actions ([Scalley et al., 2015](#)).

In response to the BoM's severe or extreme heatwave warning, the Victoria's Department of Health may issue a heat health warning. The Chief Health Officer may also issue a heat health warning when they consider forecast temperatures pose a health risk for example a single day of extremely high temperatures ([HealthVic, n.d.](#)). Warnings are disseminated widely through BoM's online portals, mobile app, telephone service, and media outlets. The warnings include action statements that match the heatwave severity. These have been agreed with our partner health and emergency service agencies across Australia, and complement heat health messages provided by state and territory agencies.

During January 2026, BoM forecasts and warnings were timely and accurate. On 5 January, BoM warned that a multi-day extreme heatwave would affect large parts of the country, providing approximately 2-4 days of lead time before peak conditions ([ABC, 2026](#)). Severe to extreme heatwave warnings were issued for extensive areas from Western Australia to Tasmania between 7 and 10 January. State health authorities acted on these warnings, issuing heat health alerts and updates, including Watch and Act alerts in Western Australia and heat health warnings in Victoria ([HealthVic, n.d.](#); [WA Country, 2026](#)).

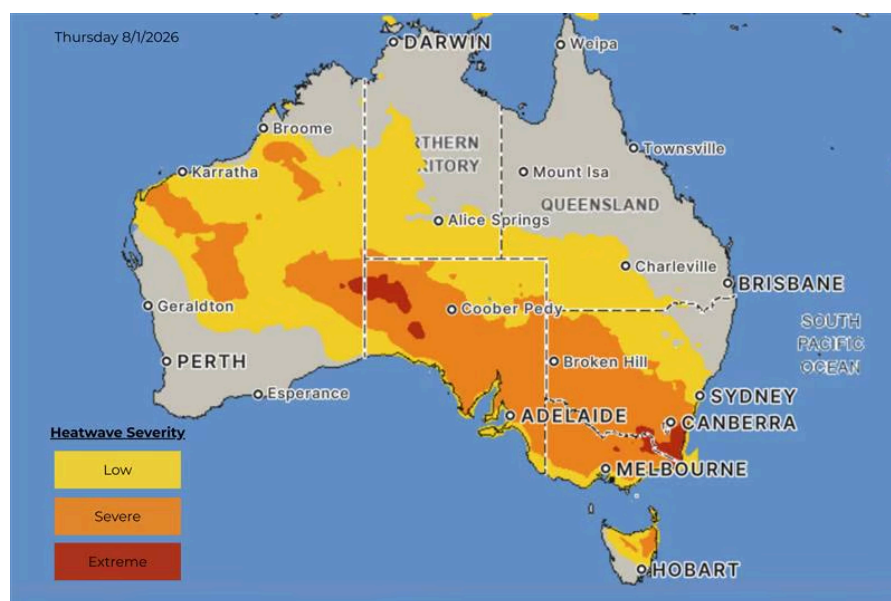


Figure 3.3: Bureau of Meteorology's (BoM's) heatwave severity maps providing early warnings of severe and extreme conditions during the heatwave of January 2026. Source: [ABC, 2026](#)

3.4.4 Emergency response

During the 2026 January heatwave, local governments and community organizations activated practical measures to reduce acute exposure among high-risk groups. In Melbourne, community safety officers distributed “cool kits” containing water, electrolyte drinks, fans, and maps to aid-conditioned spaces to people experiencing homelessness ([The Guardian, 2026](#)). Several councils expanded access

to cooling infrastructure; for example, the City of Canterbury-Bankstown extended opening hours of libraries and swimming pools to function as informal heat refuges ([The Guardian, 2026b](#)), consistent with evidence that Australian cooling centres are largely locally managed rather than embedded in state emergency plans ([Dufty, 2022](#)). In Sydney, frontline outreach similarly intensified: homelessness services reported engaging people who had left social housing because facilities were hot, while distributing hundreds of bottles in major public spaces ([City of Sydney, 2026](#)).

Adaptive responses also involved modifying social and economic activities. Outdoor sport events were cancelled in parts of New South Wales, while concerns were raised about heat safety at large music festivals, reinforcing organizer responsibility for shade and water provisions ([9News, 2026](#)). Community-based care systems also played a critical role: in-home care providers prioritized high-risk clients through activated heatwave response plans ([ABC, 2026](#)), while South Australia's Telcross REDi program provided welfare check-ins for vulnerable residents.

Further, the Victorian and Australian governments provided financial relief through the Prolonged Power Outage Payment (PPOP), supporting residents affected by extended electricity disruptions associated with the January 2026 bushfires and concurrent extreme heat, which compromised access to cooling and essential services ([Victorian Government, 2026](#)).

3.4.5 Individual and household coping behaviors

Media coverage during the 2026 January heatwave frequently depicted Australians seeking relief at beaches, rivers, and public pools, particularly in Sydney. While such imagery reflects common and often effective cooling practices, it can also counteract risk focused headlines, contributing to a persistent “fun in the sun” framing that may reduce perceived severity and normalize exposure. At the same time, advocacy groups highlighted less visible risks in everyday settings: Sweltering Cities documented surface temperatures of 69°C at a Melbourne tram stop, underscoring the limits of individual coping in heat-exposed urban environments ([The Guardian, 2026](#)).

Community-led initiatives complemented household strategies. On the South Coast, retrofitted community buildings were opened as cool, safe spaces with power, air conditioning, and social activities, designed to remain operational during extreme heat and bushfires ([ABC, 2026](#)). Cooling hubs also began to feature in mainstream media coverage, broadening narratives of heat to include vulnerability and risk, particularly for people without access to safe shelter ([City of Sydney, 2026](#)). Evidence from previous Australian heatwaves shows that coping capacity is uneven: protective factors include air conditioning, education, hydration, and social connectedness ([Zhang et al., 2015](#)), while energy insecurity and poor housing constrain adaptive behaviours for low-income and Indigenous households ([Li et al., 2024](#); [Longden et al., 2022](#); [Middha & Willand, 2023](#)).

3.4.6 Risk perception

Despite a strong warning system and communication, a major challenge remains that many people underestimate the danger of heatwaves, leading to limited behavior change even when warnings are issued. Studies indicate that awareness of heatwave alerts, especially among vulnerable populations, is not universal. For example, a survey in 2012 in Adelaide found that fewer than one-quarter of Australians are very concerned about their own health during heatwaves, even as most follow heat

news closely and worry more about societal impacts than personal effects ([Akompab et al., 2013](#)). A 2022 survey of older Australians in Queensland found only 43% recalled ever hearing a heatwave warning, and of those, barely half actually changed their behavior as a result ([Oberai et al., 2024](#)). Higher knowledge and perception of heat-related health risks in older adults were found to be associated with higher likelihood of attention to warnings and behavioural changes. A study by Williams et al. ([2018](#)) examining public responses to heat-health warnings in regional South Australia and Victoria found high levels of warning recall and general awareness, but variable effects on behavior. Notably, women perceived greater heat risks than men, but risk perception declined with age. These findings and others highlight the importance of accessible, multi-lingual messages which encourage behavioral change, especially in groups with lower risk perception and higher vulnerability.

4 Summary of findings

The analysis of temperature extremes in observations and models across the study region and at individual stations unsurprisingly reinforces the same clear conclusion as observed in every other heatwave across the globe ([Clarke et al., 2022](#)): extreme heat in Australia has become more frequent and more intense due to human-induced climate change and it is a trend that will continue to persist as long as greenhouse gas concentrations in the atmosphere continue to increase. The influence of anthropogenic climate change substantially outweighs natural climate variability, resulting in heat extremes occurring even in periods when cooler conditions would otherwise be expected.

While not the focus of this study, fire weather conditions in Victoria in late 2025 were extreme, with a combination of intense heat, strong winds, and unusually warm and dry conditions across a large area. These factors contributed to the development of multiple large, fast-spreading wildfires, creating conditions that are difficult to control and that substantially increase the risk of property damage and loss of life.

Despite comparable temperatures and elevated fire weather risk, the impacts associated with the January 2026 heatwave did not directly mirror those of earlier, highly deadly extreme events such as 2009 and 2019–2020, suggesting that some degree of adaptation has occurred. Nevertheless, risks remain substantial. Heatwaves are already placing acute pressure on Australia's health system as the most deadly natural hazard and with further impacts extending beyond physical illness and mortality. During recent heat events, emergency departments in Melbourne and Sydney reported sharp increases in patient presentations, particularly among elderly people, those without access to air conditioning, outdoor workers, and individuals with pre-existing health conditions. In regional South Australia, clinicians also reported worsening mental health presentations linked to extreme heat.

Evidence indicates that heat vulnerability in Australia has shifted over time, from primarily affecting elderly people living alone to increasingly impacting populations experiencing socio-economic disadvantage and chronic illness, including people who are unhoused and foreign-born communities. This shift underscores the need for adaptive, equity-focused heat-health policies. Despite Australia's advanced heat warning systems, many people, particularly elderly and vulnerable populations, are not aware of heatwave alerts or do not act on them. Given strong evidence that risk awareness influences behavioural response, there is a clear need for more targeted, impact-based communication to translate

warnings into effective risk reduction, including media reporting that avoids stereotypical imagery that downplays risk.

From an energy perspective, record daytime electricity demand during the heatwave was met more smoothly than in past events, largely due to abundant renewable generation. Solar power alone supplied over 60% of midday electricity, and substantially more when combined with wind and hydro, helping to keep prices stable. This represents a marked contrast to earlier heatwaves, when coal and gas plants struggled to meet demand.

Heat impacts remain most concentrated in urban areas, where geography and the urban heat-island effect amplify temperatures, particularly in neighbourhoods with high concentrations of vulnerable populations that face additional indoor heat that surpass health safety levels for several consecutive days during heat events. While progress has been made in heat-resilient urban design, it remains a critical priority. At the same time, it is important not to focus exclusively on cities: significant heat impacts also occur beyond urban areas, particularly among Torres Strait Islander and Aboriginal communities, where risks are frequently under-recognised.

Data availability

All time series used in the attribution analysis are available via the Climate Explorer.

References

All references are given as hyperlinks in the text.

Appendices

A1 Data and methods

A1.1 Observational data

We first use observational and reanalysis data to estimate the return period of a similar event in the present day and to assess the historical trends with increasing GMST. The datasets used are as follows:

- **ERA5** - The European Centre for Medium-Range Weather Forecasts's 5th generation reanalysis product, ERA5, is a gridded dataset that combines historical observations into global estimates using advanced modelling and data assimilation systems ([Hersbach et al., 2020](#)). We use daily maximum and minimum temperature data from this product at a resolution of $0.5^\circ \times 0.5^\circ$, from the years 1950 to present. The re-analysis is available until the end of the preceding month (December 2025). We extend the re-analysis data with the ECMWF analysis and the ECMWF forecast to cover the period of the event.
- **MSWX** - The Multi-Source Weather dataset ([Beck et al., 2022](#)), which combines various observational and reanalysis-based data (including ERA5) for reliable bias-corrected weather variable estimates, at 3-hourly intervals from 1979 to near real-time, and at 0.1° spatial resolution globally. We use daily maximum temperature data from this product.
- **Berkeley** - Berkeley Earth land and ocean gridded temperature data ([Rohde & Hausfather, 2020](#)). Global datasets begin in 1850, with some land-only areas reported back to 1750. We use daily maximum temperature from 1897 to 2024 at $1^\circ \times 1^\circ$ resolution, available from the [Berkeley Earth website](#).
- **AGCD** - The Australian Gridded Climate Data ([Evans et al. 2020](#)), is a high-quality observation-based gridded dataset of Australian climate variables covering the period from 1910 to present at 0.05° spatial resolution.
- **MERRA2** - Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) is a reanalysis dataset ([Gelaro et al., 2017](#)) produced by NASA's Global Modeling and Assimilation Office (GMAO). MERRA-2 provides data beginning in 1980 until near-real time. MERRA-2 assimilates various observational datasets into the Goddard Earth Observing System (GEOS) model.

As a measure of anthropogenic climate change we use the (low-pass filtered) global mean surface temperature (GMST), where GMST is taken from the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Science (GISS) surface temperature analysis (GISTEMP, [Hansen et al., 2010](#) and [Lenssen et al. 2019](#)).

As a measure of the El Niño - Southern Oscillation cycle (ENSO) we use the detrended Niño3.4 index. This is computed from [NOAA's ERSST v.5](#) sea surface temperatures, by subtracting the mean tropical SST (20S-20N) from the mean SST over the Niño3.4 region (5S-5N, 170W-120W). This index is therefore adjusted to remove the linear trend associated with climate change as proposed in [van Oldenborgh et al., 2021](#), but without rescaling each calendar month.

As a measure of the Indian Ocean Dipole, we use the 'Dipole Mode Index' (DMI; [Saji & Yamagata, 2003](#)), a gradient in average sea surface temperatures between two regions of the Indian Ocean. Specifically, this index is the difference between the western equatorial Indian Ocean (WTIO), bounded by 50-70E and 10S-10N, and the southeastern equatorial Indian Ocean (SEIO), bounded by 90-110 E and 10S-0N. This is computed from [NOAA's ERSST v.5](#) sea surface temperatures.

A1.1.1 Additional figures

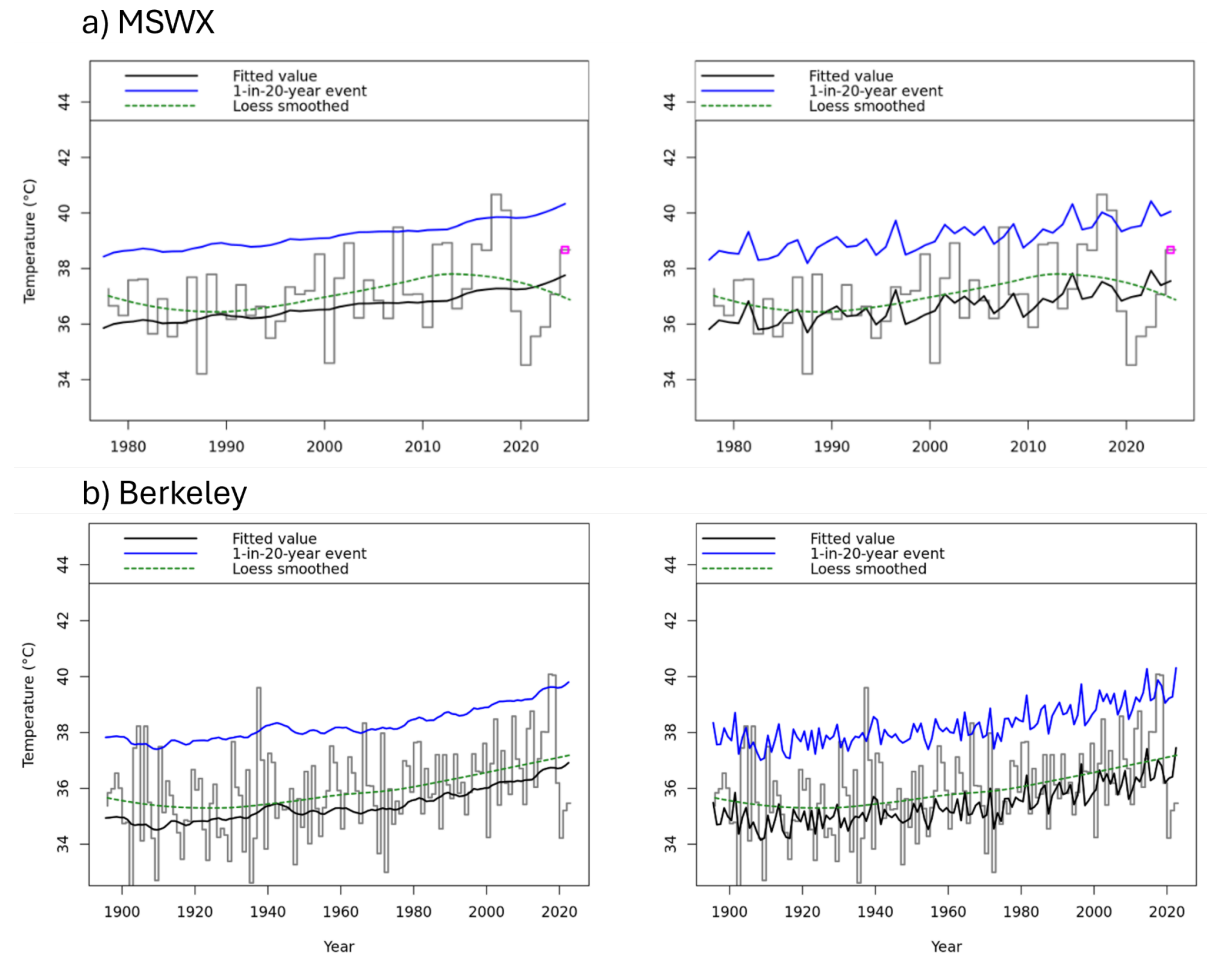
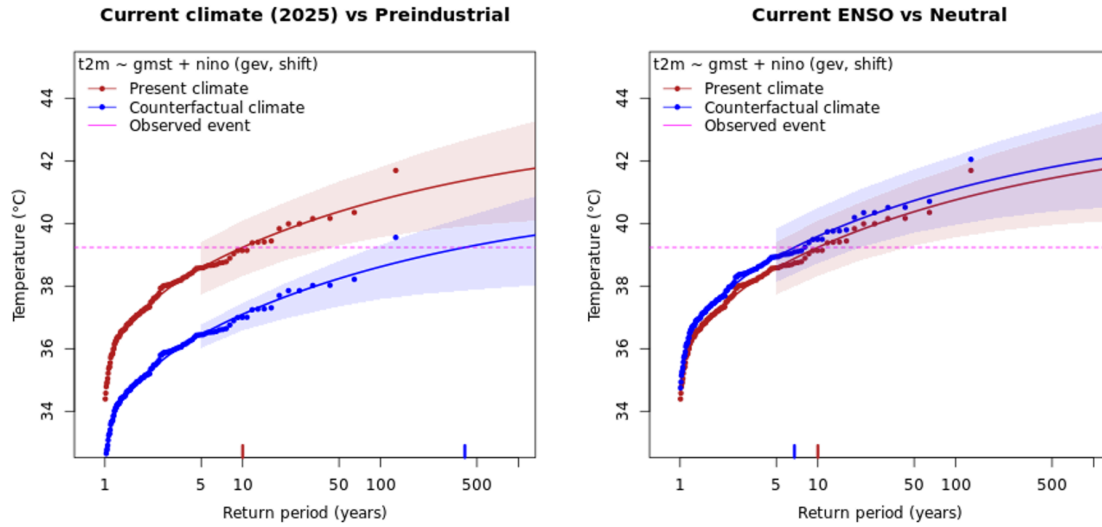


Figure A1: Time series of T_{x3x} in a) MSWX and b) Berkeley. The modelled influence of GMST (left) and GMST & ENSO on the expected value (20- year return period value) is shown with the black line (blue line), while the loess smoothed trend is shown with the green dashed line. The purple box shows the magnitude of the observed event in MSWX.

a) MSWX



b) Berkeley

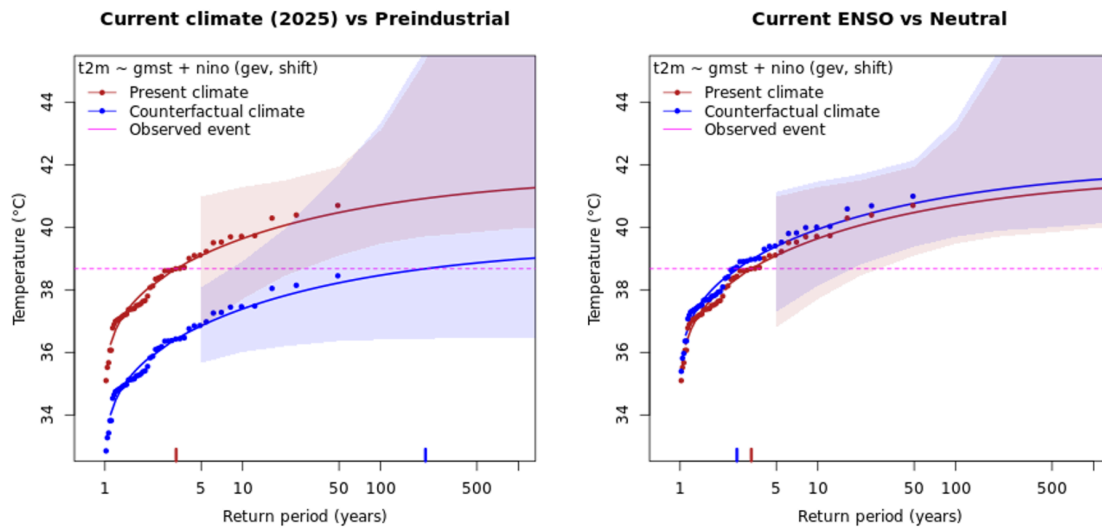


Figure A2: Statistical fits to $Tx3x$, in a) MSWX and b) Berkeley. The influence of the current GMST (left) and ENSO (right) conditions is shown with the red vs blue probability curves, showing the present vs preindustrial warming levels (left), and La Niña vs Neutral conditions (right). The magnitude of the event is highlighted with a horizontal purple line.

A1.2 Model and experiment descriptions

We use 2 ensembles of climate models from climate modelling experiments using very different framings ([Philip et al., 2020](#)): Sea Surface Temperature (SST) driven global circulation high resolution models, coupled global circulation models and regional climate models.

1. Coordinated Regional Climate Downscaling Experiment (CORDEX)-Australasia (0.44° and 0.22° resolution, AUS-44 and -22) multi-model ensemble ([Evans et al., 2021](#)), comprising of simulations

resulting from pairings of 7 Global Climate Models (GCMs) and 5 Regional Climate Models (RCMs). These simulations are composed of historical simulations up to 2005, and extended to the year 2100 using the RCP8.5 scenario.

2. CMIP6. This consists of simulations from 19 participating models with varying resolutions. For more details on CMIP6, see [Eyring et al., \(2016\)](#). For all simulations, the period 1850 to 2014 is based on historical simulations, while the SSP5-8.5 scenario is used for the remainder of the 21st century.

A1.3 Statistical methods

Methods for observational and model analysis and for model evaluation and synthesis are used according to the World Weather Attribution Protocol, described in [Philip et al., \(2020\)](#), with supporting details found in [van Oldenborgh et al., \(2021\)](#), [Ciavarella et al., \(2021\)](#), [Otto et al., \(2024\)](#) and [here](#). The key steps, presented in sections 3-6, are: (3) trend estimation from observations; (4) model validation; (5) multi-method multi-model attribution; and (6) synthesis of the attribution statement.

In this report we analyse time series of the annual maximum 3-day mean of daily maximum temperatures over the study region in southern and eastern Australia, and the same for 2-day maxima in the North Island of New Zealand. A nonstationary generalised extreme value distribution is used to model Tx3x and Tx2x. The distribution is assumed to shift linearly with the covariates, while the variance remains constant. The parameters of the statistical model are estimated using maximum likelihood.

For each time series we calculate the return period and intensity of the event under study for the 2024 GMST and for 1.3 C cooler GMST: this allows us to compare the climate of now and of the preindustrial past (1850-1900, based on the [Global Warming Index](#)), by calculating the probability ratio (PR; the factor-change in the event's probability) and change in intensity of the event.

In order to examine the effect of the ENSO phase on Tx3x alongside that of increasing GMST, we extend the nonstationary model to accommodate an additional covariate. The variable of interest, X , is assumed to follow a GEV distribution in which the location and scale parameters vary with both GMST and ENSO:

$$X \sim GEV(\mu, \sigma, \xi \mid \mu_0, \sigma_0, \alpha, \beta, T, I),$$

where X denotes the variable of interest, rainy-season precipitation; T is the smoothed GMST; I is the detrended Niño3.4 index; μ_0 , σ_0 and ξ are the location, scale and shape parameters of the nonstationary distribution; and α , β are the trends due to GMST and ENSO, respectively. As a result, the location and scale of the distribution have a different value in each year, determined by both the GMST and Niño3.4 states. Maximum likelihood estimation is used to estimate the model parameters, with

$$\mu = \mu_0 + \alpha T + \beta I \quad \text{and} \quad \sigma = \sigma_0.$$

Under this model, the effects of GMST and the detrended Niño3.4 index are assumed to be independent of one another, so that the change in intensity due to GMST is unaffected by the change in intensity due to the ENSO phase. We note that this may not be the case in the real world, as the intensity and frequency of El Niño events may have been influenced by climate change ([Cai et al., 2021](#)); however, by using a detrended Niño3.4 index (see Section 2.1) we aim to minimise the correlation between the two factors, and so do not expect the qualitative findings of this study to be affected by this simplifying assumption.

A1.3.1 Estimation of return periods with multiple covariates

Extra care must be taken when reporting and interpreting return periods that depend on more than one covariate. Typically, WWA reports estimated return periods for the event of interest under current climatic conditions: that is, with the GMST fixed at the 2025 level. In this study, there are two covariates to consider for part of the analysis: the GMST and ENSO. By fixing both the ENSO and the GMST at their 2025 levels, we can estimate the return period of the 2025 event in the current climate and in the current ENSO state. Mathematically, this return period is written as

$$1 / P(X > x_{2025} | T = t_{2025}, D = d_{2025}),$$

where x_{2025} is the 2024 value of observed precipitation; t_{2025} denotes the 2025 GMST; and d_{2025} denotes the 2024 IOD. Altogether, the expression in brackets gives the probability that X will exceed x_{2025} , given that $T = t_{2025}$ and $D = d_{2025}$; inverting this probability gives us an expected return period, in years.

However, this return period only tells us the probability of experiencing a similar event under current IOD conditions and current warming levels. In order to understand how frequently such an event is actually likely to occur, we must account for the fact that the IOD is not often in the strongly positive phase observed in 2025. To do this, we evaluate the return period over all states of the IOD that have been recorded since 1980 (the period covered by the available gridded data products). This is done by first averaging the probability of exceeding x_{2025} over all recorded values of d_{2025} during this period, then inverting to obtain the return period:

$$1 / \sum_{y=1980}^{2025} P(X > x_{2025} | T = t_{2025}, D = d_y).$$

A1.3.2 AIC scores for covariates combinations

Dataset	Model covariates - aic scores			
	GMST	GMST + SON Nino3.4	GMST + IOD	GMST + SON Nino3.4 + IOD

MSWX	169.8684	169.1579	171.863	169.0509
ERA5	271.4977	262.4941	273.2403	261.0491
MERRA2	166.1856	160.2729	168.0686	161.4843
Berkeley	453.6554	446.2441	455.6157	447.5696

Table A1: AIC scores for different combinations of covariates for four different observational and reanalysis datasets. Lower scores indicate a better fit given the relative complexity of the model, for each dataset. The lowest scoring combination for each dataset is highlighted in bold text.

A2 Model evaluation

A2.1 Tables

Model / Observations	Seasonal cycle	Spatial pattern	Sigma	Shape parameter	Conclusion
Berkeley			1.36 (1.16 ... 1.52)	-0.24 (-0.36 ... -0.15)	
ERA5			1.34 (1.07 ... 1.56)	-0.28 (-0.48 ... -0.14)	
AGCD			1.27 (1.09 ... 1.42)	-0.20 (-0.36 ... -0.091)	
MSWX			1.34 (0.912 ... 1.84)	-0.32 (-0.91 ... 0.041)	
MODELS					
CMIP6					
ACCESS-CM2	good	good	1.78 (1.28 ... 2.20)	-0.36 (-0.61 ... -0.16)	good
ACCESS-ESM1-5	good	good	1.43 (1.15 ... 1.69)	-0.17 (-0.47 ... -0.017)	good
AWI-ESM-1-REcoM	reasonable	reasonable	1.92 (1.50 ... 2.23)	-0.29 (-0.63 ... -0.064)	reasonable
BCC-CSM2-MR	reasonable	good	1.62 (1.29 ... 1.94)	-0.25 (-0.49 ... -0.034)	reasonable
CanESM5	reasonable	reasonable	1.77 (1.40 ... 2.19)	-0.29 (-0.75 ... -0.11)	reasonable
CMCC-ESM2	good	reasonable	2.00 (1.56 ... 2.45)	-0.15 (-0.48 ... 0.048)	reasonable
EC-Earth3-Veg-LR	good	reasonable	2.12 (1.60 ... 2.56)	-0.46 (-0.73 ... -0.32)	reasonable
GFDL-CM4	good	good	1.84 (1.42 ... 2.15)	-0.23 (-0.62 ... -0.052)	reasonable
INM-CM4-8	good	reasonable	1.43 (1.14 ... 1.66)	-0.32 (-0.59 ... -0.14)	reasonable

INM-CM5-0	good	good	1.25 (0.965 ... 1.49)	-0.16 (-0.40 ... 0.12)	good
IPSL-CM6A-LR	reasonable	reasonable	1.57 (1.20 ... 1.86)	-0.33 (-0.53 ... -0.16)	reasonable
KACE-1-0-G	good	good	1.05 (0.729 ... 1.26)	-0.18 (-0.56 ... 0.057)	good
KIOST-ESM	bad	bad	2.35 (1.52 ... 2.95)	-0.57 (-0.84 ... -0.24)	bad
MIROC6	bad	bad	2.49 (1.97 ... 2.96)	-0.39 (-0.70 ... -0.20)	bad
MPI-ESM1-2-LR	good	good	1.62 (1.22 ... 1.93)	-0.27 (-0.46 ... -0.045)	good
MRI-ESM2-0	good	good	1.69 (1.25 ... 2.04)	-0.32 (-0.65 ... -0.083)	good
NESM3	bad	bad	1.63 (1.15 ... 2.02)	-0.26 (-0.54 ... 0.0052)	bad
NorESM2-LM	good	good	1.23 (0.912 ... 1.69)	-0.22 (-0.81 ... 0.062)	good
NorESM2-MM	good	good	1.37 (1.07 ... 1.66)	-0.17 (-0.62 ... -0.012)	good
CORDEX					
AUS-22_HadGEM2-ES_CCLM5-0-15	good	good	2.20 (1.60 ... 2.64)	-0.66 (-0.91 ... -0.28)	reasonable
AUS-22_HadGEM2-ES_REMO2015	reasonable	good	1.62 (1.28 ... 1.90)	-0.25 (-0.53 ... -0.055)	reasonable
AUS-22_MPI-ESM-LR_CCLM5-0-15	good	good	1.76 (1.33 ... 2.08)	-0.21 (-0.51 ... 0.058)	good
AUS-22_MPI-ESM-LR_REMO2015	good	good	1.38 (1.04 ... 1.65)	-0.33 (-0.56 ... -0.15)	good
AUS-22_NorESM1-M_CCLM5-0-15	good	good	1.72 (1.28 ... 2.07)	-0.17 (-0.43 ... 0.10)	good
AUS-22_NorESM1-M_REMO2015	good	good	1.40 (1.11 ... 1.64)	-0.20 (-0.44 ... 0.033)	good
AUS-44_ACCESS1-0_WRF360J	good	good	1.67 (1.29 ... 1.99)	-0.29 (-0.54 ... -0.14)	good
AUS-44_ACCESS1-0_WRF360K	good	good	1.73 (1.33 ... 2.14)	-0.29 (-0.61 ... -0.096)	good
AUS-44_ACCESS1-3_WRF360J	good	good	1.66 (1.07 ... 2.01)	-0.21 (-0.37 ... 0.16)	good
AUS-44_ACCESS1-3_WRF360K	good	good	1.56 (1.11 ... 1.89)	-0.27 (-0.48 ... -0.061)	good
AUS-44_CanESM2_WRF360J	good	good	1.44 (1.16 ... 1.70)	-0.19 (-0.62 ... -0.026)	good
AUS-44_CanESM2_WRF360K	good	reasonable	1.31 (0.970 ... 1.56)	-0.13 (-0.26 ... 0.13)	reasonable
AUS-44_EC-EARTH_CCLM4-8-17-CLM3-5	good	reasonable	1.67 (1.28 ... 1.98)	-0.38 (-0.60 ... -0.19)	reasonable

AUS-44_MPI-ESM-L R_CCLM4-8-17-CLM 3-5	good	good	1.79 (1.31 ... 2.17)	-0.41 (-0.63 ... -0.20)	good
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Table A2: Evaluation results of the climate models considered for attribution analysis of Tx3x. For each model, the threshold for a 1-in-5-year event is shown, along with the best estimates of the Sigma and Shape parameters are shown, along with 95% confidence intervals. Furthermore evaluation of the seasonal cycle and spatial pattern are shown.

A2.2 Figures

Seasonal cycle of temperatures in ERA5, Berkeley & CMIP6

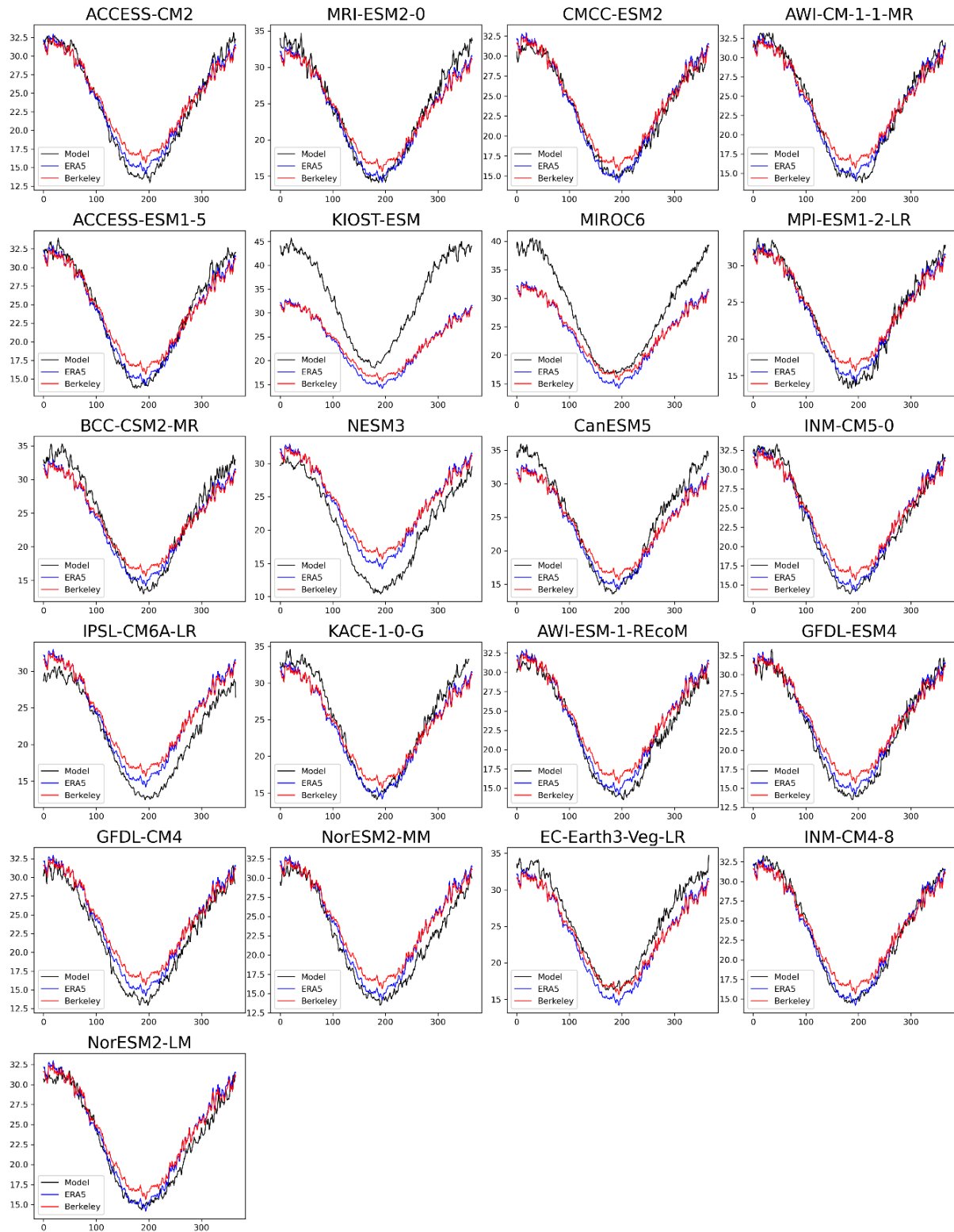


Figure A3: Climatological (1991-2020) seasonal cycles of the daily maximum temperature in the study region in CMIP6 climate models (black line), ERA5 (blue line), and Berkeley (red line).

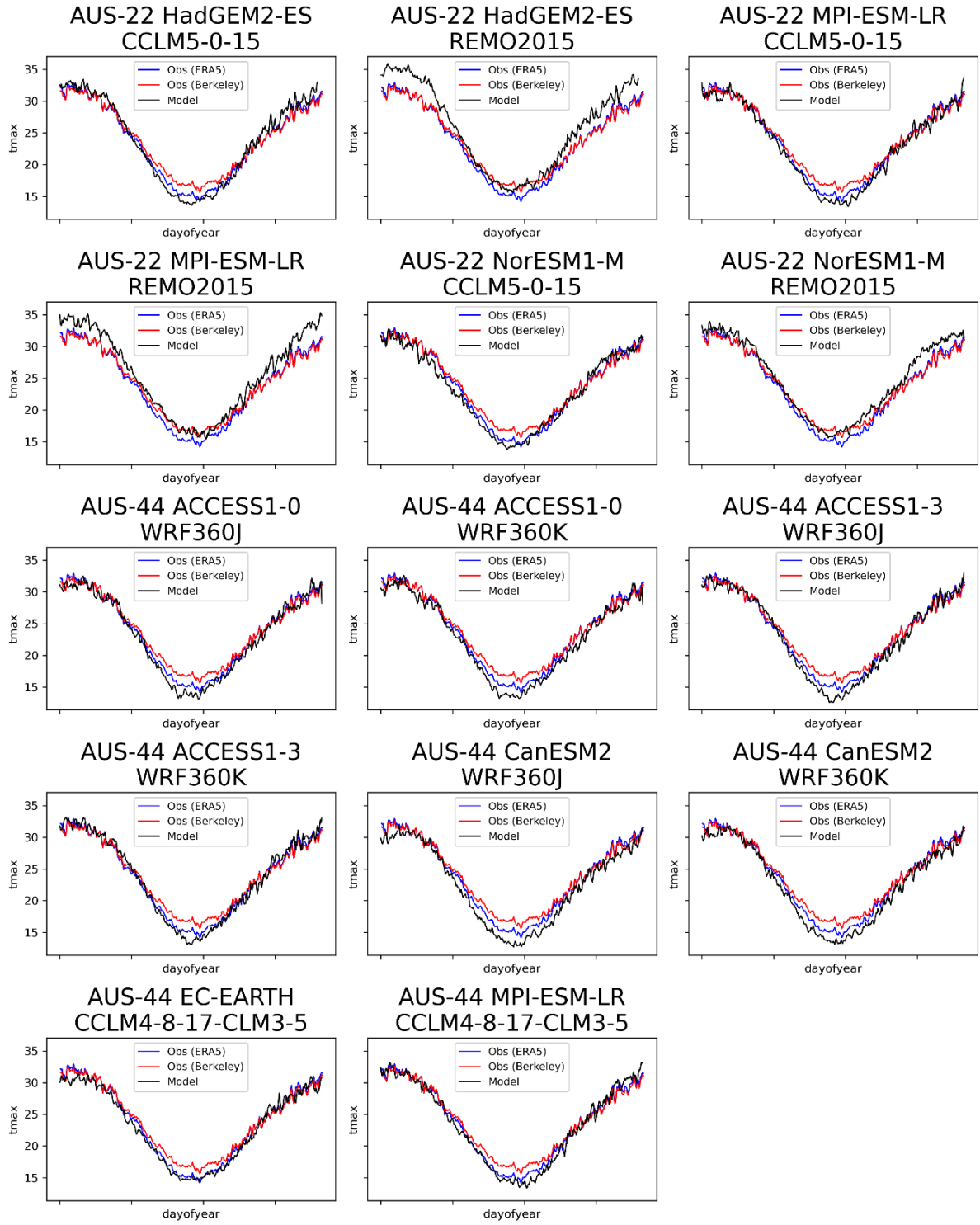


Figure A4: Climatological (1991-2020) seasonal cycles of the daily maximum temperature in the study region in CORDEX-AUS climate models (black line), ERA5 (blue line), and Berkeley (red line).

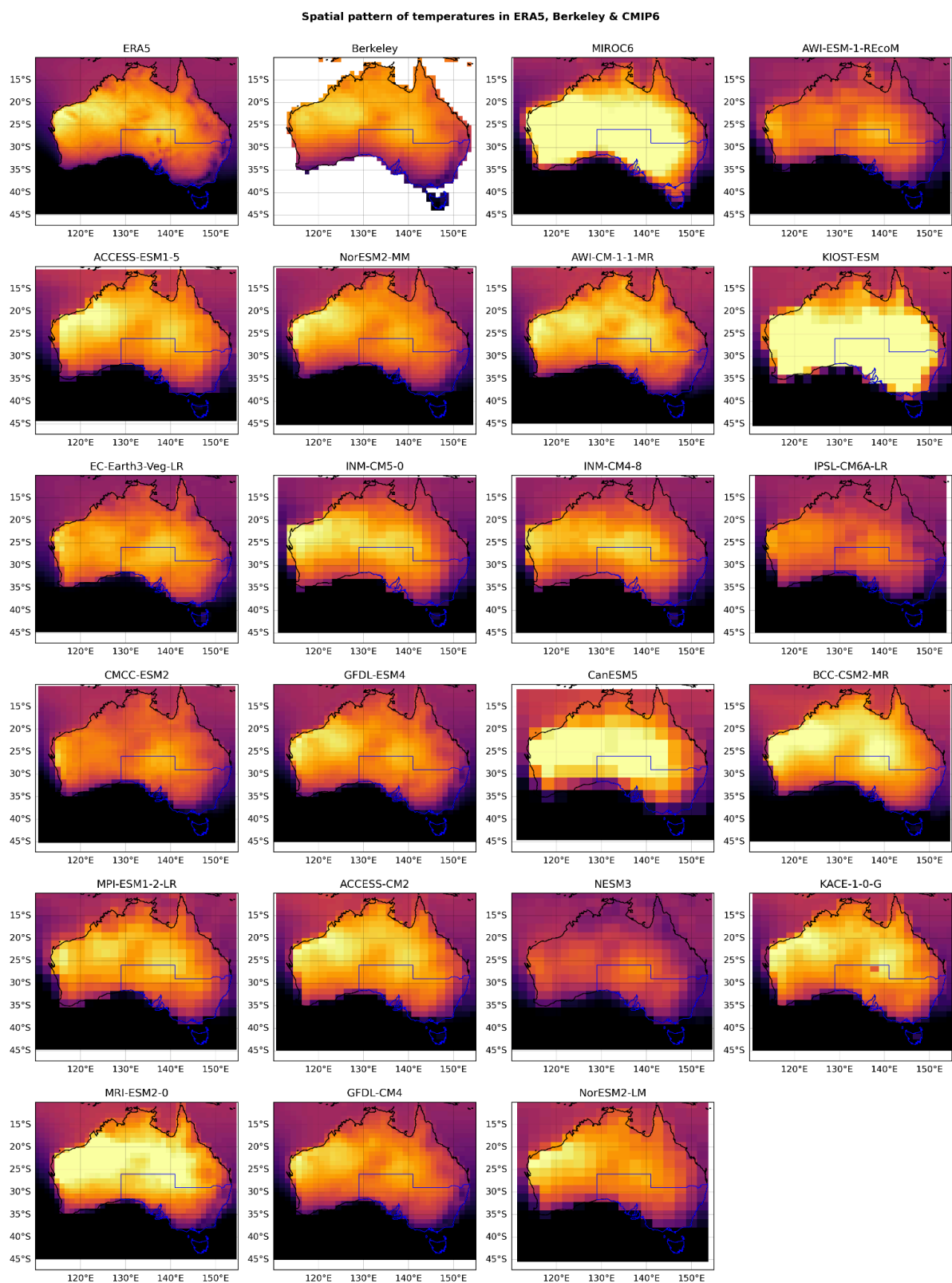


Figure A5: Climatological (1991-2020) spatial patterns of the daily maximum temperature for summer months (December-February) in the study region in CMIP6 climate models and ERA5 and Berkeley.

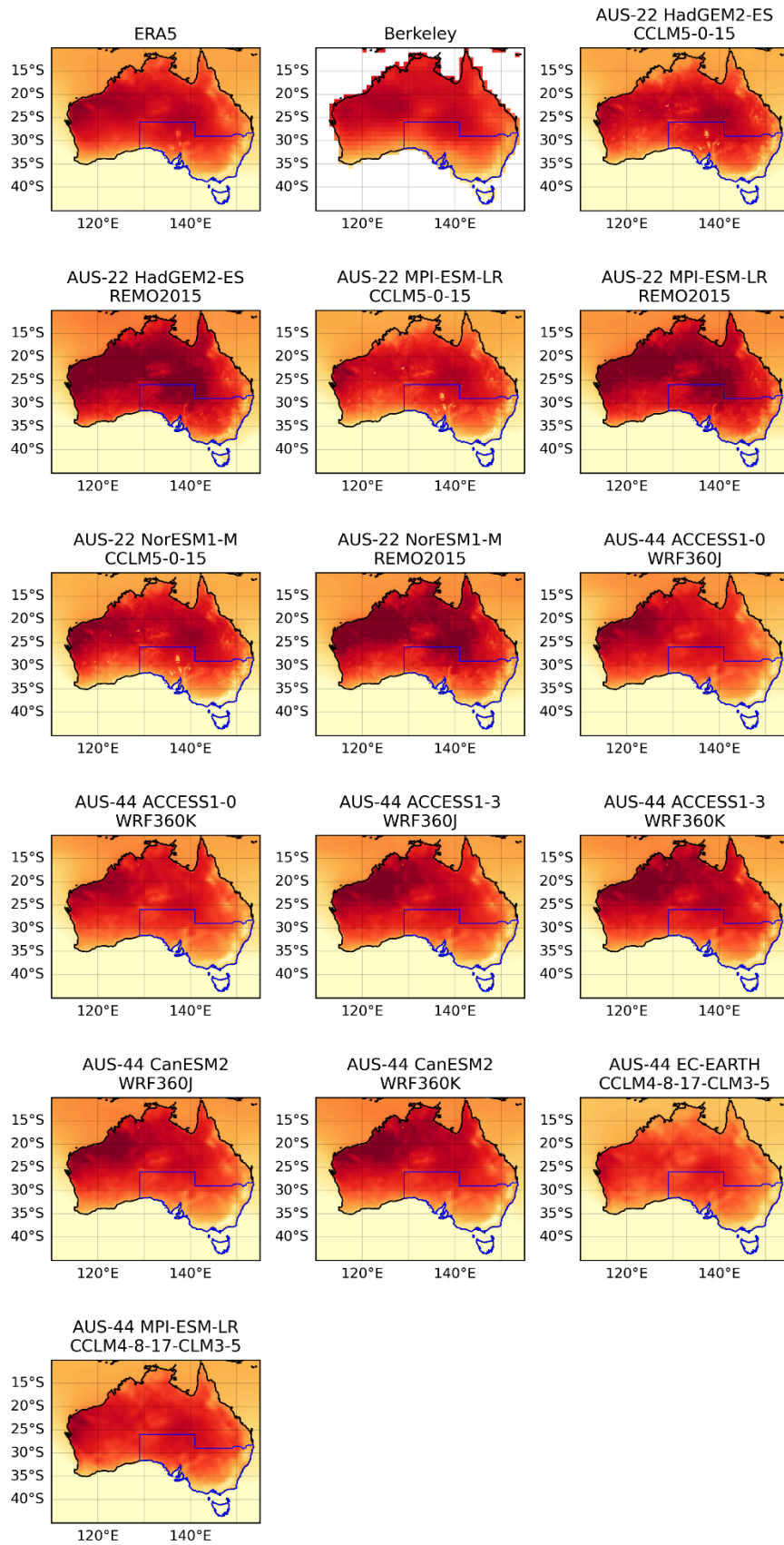


Figure A6: Climatological (1991-2020) spatial patterns of the daily maximum temperature for summer months (December-February) in the study region in CORDEX-AUS climate models and ERA5 and Berkeley.