QUEENSLAND

STATE HEATWAVE RISK ASSESSMENT 2019

Queensland Government

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Thank you

The Queensland State Heatwave Risk Assessment 2019 was a collaborative effort, bringing together the expertise of multiple stakeholders. Particular thanks to Queensland Health, Department of Environment and Science, and The University of the Sunshine Coast.

Foreword from Queensland Fire and Emergency Services

Natural hazards affect the lives of all Queenslanders. We are exposed to a range of hazards which can have a significant impact on our economy, our environment and may lead to significant consequences for our communities. These hazards are becoming increasingly extreme and complex, exacerbated not only by our globally interlinked economies but also the impacts of climate change.

Within the past decade we have experienced natural disasters of a size and scale that are almost unprecedented in our nation's modern history. The extreme heatwave and associated bushfires in late 2018 are a clear indication that we face new, unparalleled challenges in understanding and responding to the impacts of climate change on natural hazards which even now pose a significant risk to Queensland.

These events reinforce the need to communicate appropriate risk information across the three tiers of Queensland's Disaster Management Arrangements (QDMA): Local, District and State.

Following the release of the State Natural Hazard Risk Assessment in 2017 and through consultation with stakeholders at all levels of QDMA, the clear need for detailed and consistent information regarding the changing nature of Queensland's risk from heatwaves was identified.

Our collective ability to assess and more deeply understand the impacts of climate change on current and future natural hazard risk is the first step towards the ongoing development of resilience in the face of more and more intense natural hazards. This approach is also reflective of the international focus on understanding disaster risk as priority one of the Sendai Framework for Disaster Risk Reduction 2015–2030.

Hon. Craig Crawford MP
Minister for Fire and Emergency Services

Katarina Carroll APM
Commissioner, Queensland Fire and Emergency Services

Starting at the Local level, the communication of consistent risk information between each tier of QDMA can support communities and government, emergency services and all emergency management partners in making informed decisions.

This assessment represents a maturing capability for informing the development of current and future risk-based plans across QDMA. The inclusion of detailed climate change projections for communities in Queensland represents a first for natural hazard-based risk assessments within the emergency management sector.

Risk-based planning is one of the cornerstone enablers for the Queensland community to be better able to prevent, be prepared for, respond to and recover from natural disasters.

As the Minister for Fire and Emergency Services, and the Commissioner of Queensland Fire and Emergency Services (QFES), we thank all stakeholders for their contribution to this assessment and the continued commitment towards creating safer and more resilient communities. We would also like to specifically thank the Department of Health and the Department of Environment and Science for partnering with QFES on this initiative, and local governments for their ongoing cooperation.

We encourage all Queenslanders affected by natural hazard risk to consider the information and strategies within this valuable assessment and use it to inform the management of risks applicable to their interests and responsibilities.

Foreword from Queensland Health

Queensland is renowned for its blistering summer temperatures and snap summer storms. For Queenslanders, that's always been a part of life but climate change is intensifying these Queensland weather traits, and as summers go on for longer and heatwaves intensify, we are seeing the effects on our health.

Severe and extreme heatwaves have taken more lives than any other natural hazard in Australia.

Queensland Health plays a critical role in responding to heatwaves – our doctors, paramedics and hospital workers are seeing more people affected by heat, directly or indirectly, than ever before.

Hon. Steven Miles MP
Minister for Health and Minister for Ambulance Services

Workshops held around the state have helped inform this report and highlighted important stories. We have consulted with Queenslanders of all backgrounds, not just those in the health sector, and taken on board important lessons and advice.

Over the last few summers we have experienced record-breaking heatwaves and seen how their impacts are intensified when they coincide with another natural disaster. We only need to look to the October 2018 bushfires, or the February 2019 North Queensland flooding, to see how heatwaves can cause further distress during times of crisis.

Many of our most vulnerable Queenslanders are particularly susceptible to these health impacts, including children, the elderly, pregnant and breastfeeding women, and people with pre-existing medical conditions. In addition to the direct effects of heat illness, heatwaves, can also cause dehydration and the spread of food-and-vector borne diseases.

Queensland Health is preparing our communities for the challenges of worsening heatwaves.

This publication will make sure the Queensland Government has an informed, prepared approach for heatwaves.

Queensland Health will continue to work with QFES and DES so we can better understand how to protect all Queenslanders from the risks of heatwaves.

Foreword from Department of Environment and Science

The Department of Environment and Science (DES) is proud to have collaborated with QFES and Queensland Health to develop the State Heatwave Risk Assessment. This assessment will be an important asset for Queensland and will inform the development of health and environmental policy as well as frontline emergency services as we face more weather extremes.

Climate change is the greatest challenge facing our planet today and it is driving more severe heatwaves, fire conditions and longer bushfire seasons, here in Queensland.

Hon. Leeanne Enoch MP

Minister for Environment and the Great Barrier Reef, Minister for Science and Minister for the Arts

Queensland is unlike anywhere else in the world. We are one of the world's most naturally diverse places, home to five World Heritage Areas, more than 1300 National Parks, marine parks, state forests and other protected areas. We also have more species than any other Australian state or territory.

But we are clearly seeing the effects climate change is having on our environment. In Queensland there have already been impacts on terrestrial ecology through changing and intensifying weather patterns. In the aquatic environment, with heating oceans, and impacts from successive severe cyclones, there have been successive mass coral bleachings, and impacts from sediment.

To help Queenslanders prepare for, and recover from, climate change impacts like heatwaves and bushfires, the Queensland Government has invested in the tools and resources necessary to inform a wider understanding of climate change.

DES recently launched the Queensland Future Climate Dashboard. The dashboard features the latest climate projections data, climate change scenarios and climate initiatives; including a special section on Heatwaves and a water-security case study.

The climate projection data was incorporated into the Statewide Heatwave Risk Assessment to support accurate, effective and timely decision making to protect Queenslanders and their lifestyles, infrastructure and resources from the impacts of heatwaves.

I trust that this assessment will help Queensland to navigate the more volatile weather we are experiencing at this time and I look forward to continuing to work together with QFES and the Department of Health to equip our state for all that is to come.

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Introduction

Purpose and intended audience

This high-level report is intended to act as the foundation of heatwave risk assessments for Local and District Disaster Management Groups (LDMGs/DDMGs), and State agencies. These assessments act to inform the development of their associated risk-based disaster, and business risk management plans.

The State Heatwave Risk Assessment 2019 (SHRA) delivers a comprehensive overview of current and future heatwave risk in Queensland, for use by all levels of government in conjunction with the Queensland Emergency Risk Management Framework (QERMF). The QERMF, as the endorsed methodology for the assessment of disaster related risk:

- Provides consistent guidance in understanding disaster risk that acts as a conduit for publicly available risk information – this approach assists in establishing and implementing a framework for collaboration and sharing of information in disaster risk management, including risk-informed disaster risk reduction strategies and plans.
- Encourages holistic risk assessments that provide an understanding of the many different dimensions of disaster risk (hazards, exposures, vulnerabilities, capability, and capacities) – the assessments include diverse types of direct and indirect impacts of disaster such as physical, social, economic, and environmental.

This risk assessment was developed using the QERMF to undertake a thorough analysis of Queensland's current and future heatwave risk.[1] Overall, the assessment and associated report seeks to complement and build upon existing Local, District and State heatwave risk assessments by providing updated and validated information relating to the changes in understanding of Queensland's heatwave potential. This assessment represents the first time the QERMF will help to inform the revision of a State level disaster management sub plan.

Background to the assessment

In 2017 Queensland Fire and Emergency Services (QFES) completed the State Natural Hazard Risk Assessment (SNHRA) which evaluated the risks presented by seven in-scope natural hazards.The SNHRA accorded the risks posed by 'severe' and 'extreme' heatwaves as the third highest priority for Queensland. Heatwaves cause substantial impacts for society and the environment in several ways including human health, agriculture, economy, natural hazards and ecosystems. Heatwaves are Australia's most costly natural disaster in terms of human impact.[2]

The development of the SHRA was a collaborative effort between multiple stakeholders coordinated through a working group led by QFES, Queensland Health (QH), and the Department of Environment and Science (DES). QH is the primary agency for managing heatwaves, as described in the Queensland State Disaster Management Plan. The management of heatwaves is currently outlined within the Heatwave Response Plan as an annex of the Queensland Health Disaster Plan.

This risk assessment process included six State level and six regional consultations (held in Longreach, Roma, Cairns, Yeppoon, Sunshine Coast, and City of Gold Coast) involving over 300 people from a diversity of subject matter expertise (see Figure 1).

The inclusion of long-term climate change projections within the assessment was made possible by the Climate Science Division, and the Climate Change and Sustainable Futures Branch, Department of Environment and Science. This collaboration represents a first for hazard specific, emergency management-related risk assessments in Australia. This robust scientific basis enhances the assessment and enables State agencies and disaster management groups to inform their planning against current and future heatwave risk.

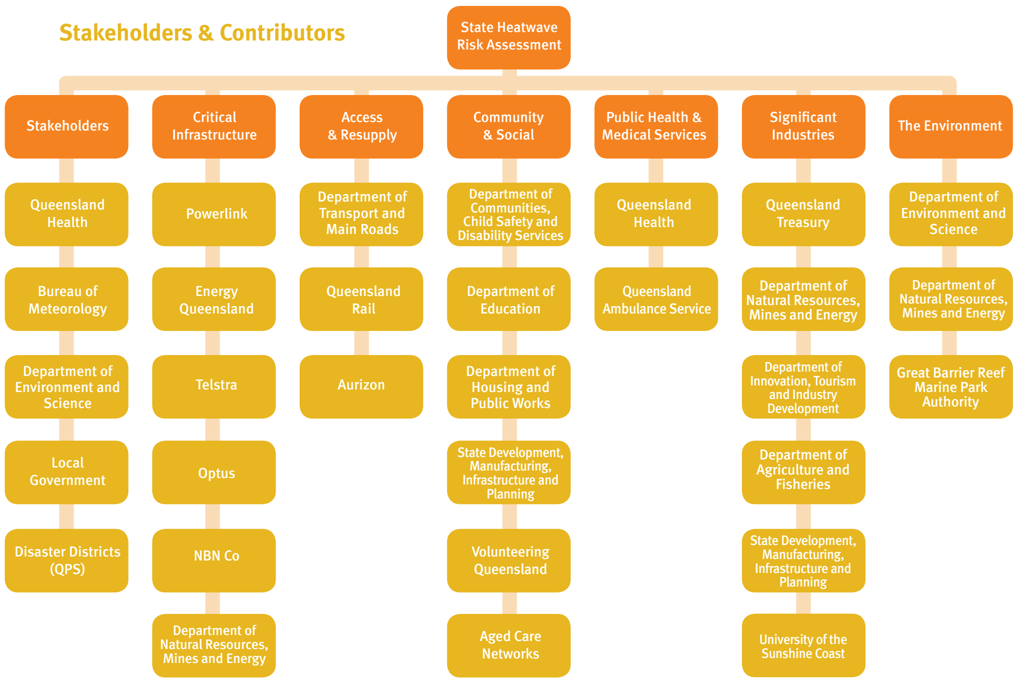


Figure 1: Stakeholders and contributors to the State Heatwave Risk Assessment process.
Source: Queensland Fire and Emergency Services

How to use this assessment within the QERMF Risk Assessment Process

The potential for prolonged and intense heatwaves in Queensland is increasing due to the impacts of climate change and other socio-natural and anthropogenic factors.[3] As a result, the associated consequences of these events are also increasing and are likely to have significant and prolonged impacts on the community as time progresses.

As outlined within Figure 2, the recommended approach for Local, District and State level assessments is to use the information contained within this document to evaluate and understand:

1. The current probability of heatwave occurrence and increase in likelihood of heatwave occurrence (based on those figures outlined within the table at Appendix A).
2. The vulnerability of the location under assessment through analysis of the local natural and built environments, and regional climatological conditions.
3. The elements of the community which may be exposed in the location under assessment (against the six QERMF categories of exposed elements) and the vulnerability of these exposed elements, noting that some elements may be exposed through broader social or economic impacts from a heatwave event (or associated hazards such as bushfire) occurring outside the region.
4. The existing controls to manage or mitigate this type of event (such as building codes, community warning strategies and specific agency disruption or continuity plans) at the respective level of Queensland's Disaster Management Arrangements (QDMA).
5. The existing capabilities at the respective level of QDMA to manage to this type of event.
6. The capacity of the identified capabilities.
7. The identified gaps in capability or issues of concern (residual risk) and how the management of these will be implemented through the passage of residual risk through QDMA.

Once steps 1 through 7 have been completed, this assessment can then be tabled for acceptance by a disaster management group for incorporation into its respective disaster management plan. If, through the implementation of this assessment, an LDMG or DDMG wishes to seek further advice or evaluation of their area of responsibility, assistance in accessing relevant expertise can be sought through the contact details provided within this report.

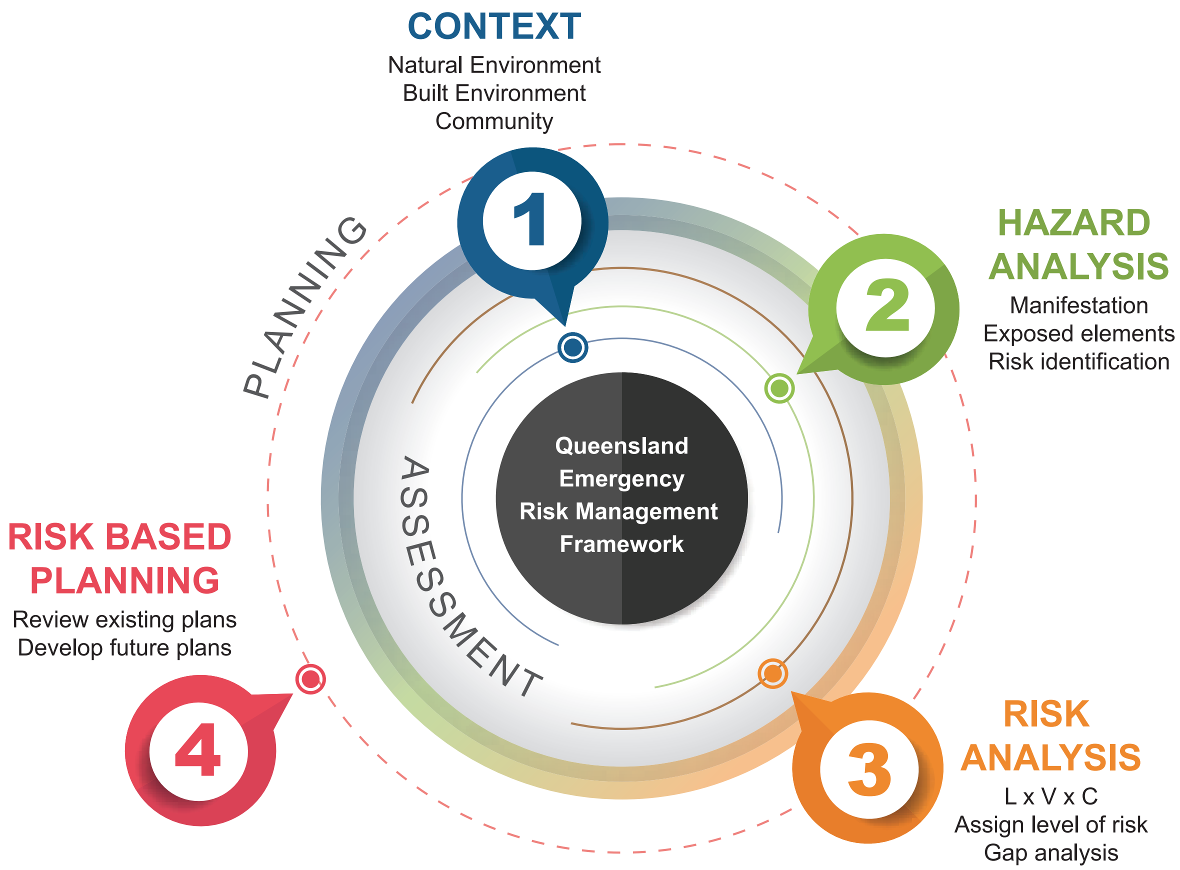


Figure 2: The Queensland Emergency Risk Management Framework's approach integrates a range of assessment elements to assist in risk-based planning. Source: Queensland Fire and Emergency Services

UNDERSTANDING THE HAZARD

Understanding the hazard

General context

What is a heatwave?

As defined by the Bureau of Meteorology (BoM), a heatwave is *"three days or more of high maximum and minimum temperatures that are unusual for that location"*.

Heatwaves are measured relative to the usual weather in the area, and relative to normal temperatures for the season in that area. Therefore, temperatures that people from a hotter climate consider normal can be termed a heatwave in a cooler area if they are outside the normal climate pattern for that area.

The combination of the 'significance index' (how hot the local temperature is compared to normal for that time of year) and the 'acclimatisation index' (comparison of temperatures over the past 30 days to indicate the rate of temperature change) takes into account people's ability to adapt to heat and if a specific heatwave event is more likely to have greater human health impacts.[4]

Accordingly, the same elevated temperatures will be felt differently by residents in Brisbane compared to those in Hobart, who are not used to the higher range of temperatures experienced in Brisbane. Similarly, temperature adaptation occurs within a local geographic area across summer as there are more hot days. This means that, in any one location, temperatures that meet the criteria for a heatwave at the end of summer will be higher than the temperatures that meet the criteria for a heatwave at the beginning of summer.

The minimum (or overnight) temperature is also an extremely important contributor to the calculation. If the minimum remains high, then the subsequent maximum will occur earlier in the day and remain near that high temperature for a longer period. A higher minimum temperature also reduces the period of respite from the heat and provides less opportunity for both people and the environment to discharge heat.

What drives heatwaves?

There is broad agreement regarding the nature of weather systems driving heatwaves in Australia – in many cases a high-pressure system sits next to the region experiencing the heatwave, pushing hot air from the centre of Australia towards that region. The location of the high depends on the region experiencing the heatwave, but there is always one present.[5] The high pressure in the upper atmosphere strengthens and stops the hot air from rising, causing it to 'sit' on the affected area.

These high-pressure systems can be created and sustained by other weather influences farther afield. For example, it has been demonstrated that heatwave occurrence in Melbourne is coupled with tropical cyclones to the north-west of Australia.[6]

This report will demonstrate the link between some of Queensland's major cyclones and significant heat events that followed, resulting in further impacts to already vulnerable communities.

Other, longer-term variables can affect not just individual heatwaves but their patterns, timing and severity. Significantly more heatwave days, and longer and more intense events, are observed over northern and eastern Australia during El Niño compared to La Niña,[7] yet different relationships occur in the south-east of the country.[8]

However, there is still a gap in our understanding of how changes under climate change to patterns such as El Niño, will influence future heatwave occurrence.[9]

Heatwave intensity and the link to risk

Most heatwaves in Australia and Queensland are of low intensity, with most people expected to have adequate capacity to cope with this level of heat. Less frequent, higher intensity heatwaves are classified as severe and can be challenging for more vulnerable people, such as those older than 65 years, pregnant women, babies and young children, and those with a chronic illness. Even rarer and exceptionally intense heatwaves are classed as extreme and will impact normally reliable infrastructure, such as power and transport. Extreme heatwaves are a risk for anyone who does not take precautions to keep cool, even those who are healthy. Figure 3 below outlines

HEATWAVE INTENSITY	COLOUR CODE	POTENTIAL COMMUNITY IMPACT
Low intensity heatwave	Yellow	Most people expected to have adequate capacity to cope with this level of heat but begin to see health effects. Increased risk to vulnerable groups.
Severe heatwave	Orange	Increased morbidity and mortality for vulnerable groups, such as those over 65, pregnant women, babies and young children, and those with chronic illness (e.g. renal disease, ischaemic heart disease).
Extreme heatwave	Red	May impact normally reliable infrastructure, such as power and transport. Health risk for anyone who does not take precautions to keep cool, even those who are healthy.

Figure 3: Recognised level of heatwave intensity as defined by the Queensland Heatwave Response Plan. Source: Queensland Health

the recognised levels of heatwave intensity and the links to potential community impacts.

Relative humidity can be an important consideration in assessing the human health effects of heatwaves. However, meteorological observations and forecasting of humidity is not as accurate as air temperature. On this basis BoM has chosen not to include it explicitly in the heatwave metric as outlined above. It does, however, have an implicit presence through the inclusion of daily minimum temperature. High humidity tends to result in high minimum temperature, and low humidity in low minimum temperatures. This is reflected in the daily mean temperature calculation published by BoM's Heatwave Service.[10]

While heatwaves are generally not considered as significant contributors to the nation's mortality rate, research shows that extreme temperatures currently contribute to the deaths of more than 1,000 people aged over 65 each year across Australia.[11] Heatwaves have been described as 'silent killers', causing more deaths since the 1890s than bushfires, cyclones, earthquakes, floods and severe storms combined.[12]

Violent weather events, such as floods, cyclones or severe thunderstorms generate significant media attention, inclusive of reporting on how many people died or were injured. Heatwaves are not associated with these violent events and therefore tend to not be reported in the media to the same extent.[13]

However, heatwaves can result in significant health stress on vulnerable people. This stress may result in death during the heat event but, in many cases, this can occur well after the heatwave has passed. Deaths during a heatwave may be direct (heat illness) or indirect (heat exacerbating the effects of existing illness or vulnerability). This means it is much harder to identify heat-related mortality until after the event has passed as many people who die during a heatwave have a pre-existing or contributing health condition.

In fact, from 1900 to 2010, extreme heat events have been responsible for at least 4,555 fatalities in Australia. This is more than the combined total of deaths from all other natural hazards (Figure 4).[14]

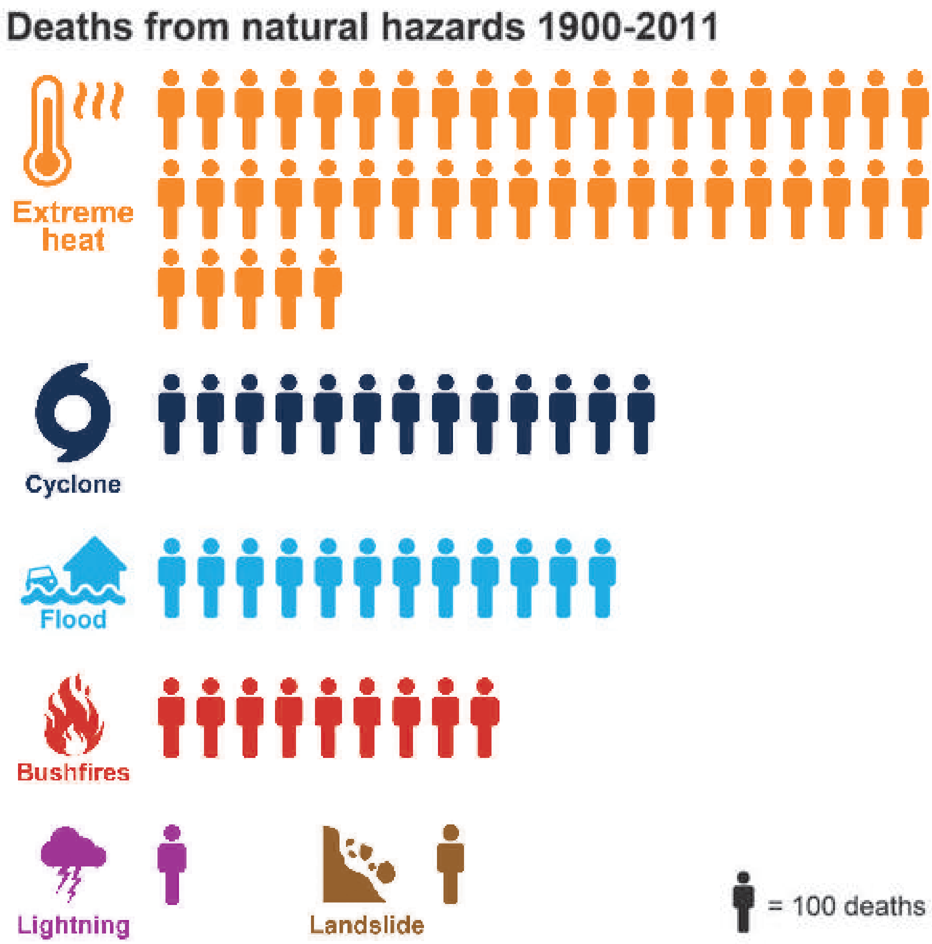


Figure 4: Infographic highlighting the mortality rate of heatwaves against other significant natural hazards within Australia. Source: Department of Environment and Science adapted from McMichael et al., 2003

Over 30 per cent of those deaths occurred in just nine events. For example, during the 2009 Victorian bushfires, 173 people perished as a direct result of the fires; however, 374 people died in the heatwave that preceded them.[15] Figure 5 shows the severity of the heatwave around the time of these fires.

Under climate change, projections of heat-related deaths suggest an increase of 1,250 deaths per year by 2070 leading to as many as 8,628 deaths per year by 2100.[16]

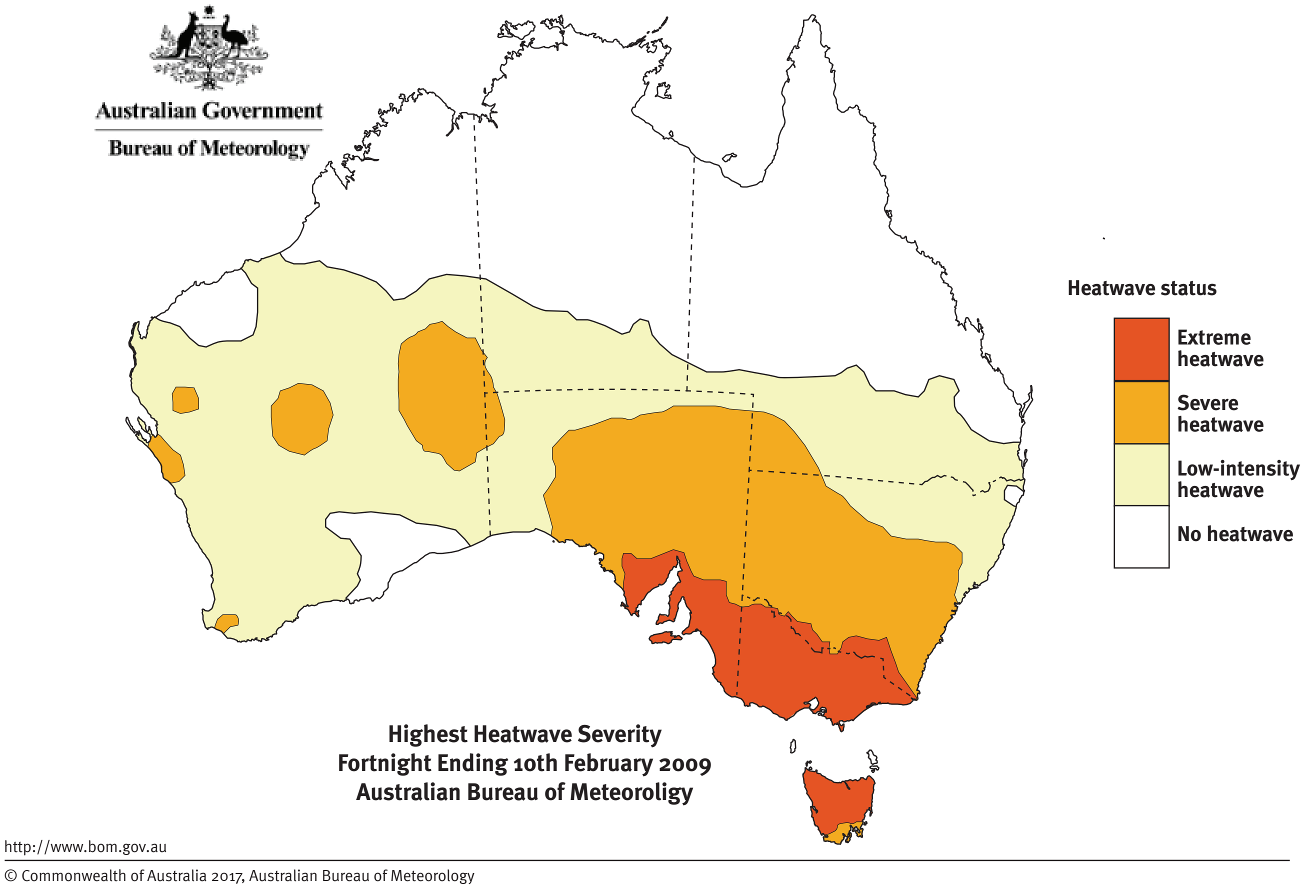


Figure 5: Highest observed heatwave severity across southern Australia during the period 27 January to 10 February 2009. The Victorian bushfires ignited on and around 7 February. Source: Bureau of Meteorology

Case study: Hot in the city – the urban heat island effect, heatwaves and human health and wellbeing

Urban areas generate higher temperatures than nearby rural areas in a phenomenon called the urban heat island effect (UHIE). Dark, heat absorbing and impermeable materials used to construct urban buildings and infrastructure radiate heat into their immediate surroundings and cool slowly at night. This, combined with the canyon-like form of cities, high density of vehicles and lack of green space, makes urban areas very hot. The urban heat island effect can cause urban temperatures to be between 2°C and 12°C higher than nearby rural areas.[17]

Accordingly, the effect of heatwaves on the health and wellbeing of urban populations is exacerbated by UHIE. Urban populations are exposed to increasing levels of heat, as lack of green space, buildings blocking air flow, and the prevalence of hard and heat-absorbing structures in urban areas have a multiplying effect. Moreover, heat-absorbing surfaces release heat slower at night, exposing people to elevated temperatures for longer.[18] Increased exposure to extreme heat means the risk of death during a heatwave is higher in urban areas than in rural areas.[19] Population groups at greatest risk of death include:

- the elderly, especially those living alone
- very young children
- outdoor workers
- people with chronic health conditions (especially cardio-vascular, renal and mental health conditions)
- homeless people
- people living with disabilities
- people in lower socio-economic brackets.

Studies of the Brisbane and Southeast Queensland regions show notable increases in fatalities, ambulance call-outs and hospital admissions during heatwaves.[20] The 2004 Brisbane heatwave resulted in a 23 per cent rise in excess deaths while the January 2000 heatwaves in the SEQ region resulted in 22 heat-related deaths.[21]

Some studies have mapped the extent of UHIE in particular local government areas (LGAs) in Queensland,[22] however, studies examining the health effects of UHIE are rare. A comprehensive study of urban heat islands in Australia identified Ipswich, Logan, Toowoomba and Cairns as the most heat exposed among the 10 LGAs analysed in Queensland.[23]

This study produced the VHHEDA Index, which stands for Vulnerability to heat, poor Health, Hot spots, Economic Disadvantage, and Access to green spaces. LGAs were assigned scores of either 0, 1 or 2 based on their level of vulnerability to the following risk factors (2 for lowest vulnerability, 0 for highest vulnerability):

- levels of heat (land surface areas compared to percentage of canopy cover)
- amount of canopy cover
- socio-economic disadvantage
- poor human health (self-assessed health, prevalence of diabetes, rate of population under five years of age and population over 65 and living alone)
- levels of growth in greening (rate of total green loss compared to canopy cover loss).

Scores for each of the risk factors were totalled to calculate a total score for each LGA. LGAs with lower total scores are most vulnerable to UHIE. A summary of results for Queensland LGAs is presented in Figure I below:

LGA	Canopy heat	Health	Economic disadvantage	Rate of canopy cover loss	Vulnerable population	Total score	Risk level
Ipswich	1	0	0	2	1	4	2
Logan	1	0	1	1	1	4	2
Toowoomba	1	1	0	2	0	4	2
Cairns	1	1	0	2	1	5	2.5
Moreton Bay	1	1	2	1	1	6	3
Sunshine Coast	1	1	2	1	1	6	3
Gold Coast	1	1	2	1	2	7	3.5
Redland	1	1	2	1	2	7	3.5
Townsville	1	1	2	2	1	7	3.5
Brisbane	1	2	2	1	2	8	4

Figure I: The VHHEDA Index identifies and quantifies the extent of UHIE in particular Queensland local government areas. Source: Amati et al., 2017

Findings of this and similar studies identify the need to retrofit, design and build urban areas in ways that reduce people's exposure to extreme heat. Some LGAs are already implementing actions to reduce UHIE. This includes planting more trees, building more shade structures, providing guidelines that encourage buildings to include passive cooling features and providing respite areas for more vulnerable groups.

Flagship project to manage the health effects of heatwaves and the urban heat island effect in Queensland

The Queensland Government is collaborating with key partners to design a flagship project to strengthen community resilience, and health and urban planning responses, to manage the impacts of heatwaves and UHIE on human health and wellbeing. The project's objectives include:

- understanding how UHIE affects health and wellbeing
- understanding how projected climate, urban development and population changes will influence health outcomes from extreme heat events
- identifying actions to strengthen health service delivery and community resilience and improve urban design.

This project will build on the findings of this State Heatwave Risk Assessment and be collaboratively designed and developed with partners from State government, local governments and stakeholders from the health, community wellbeing, emergency management and research sectors. The project is funded by the Department of Environment and Science and delivered as an action under the Queensland Climate Adaptation Strategy. The project is anticipated to be finalised by 2020.

Authored by Environmental Policy and Programs, Department of Environment and Science

Consequential hazards

A detailed understanding of the characteristics of heatwaves is essential when analysing potential impacts on an area or community. Specifically, this knowledge identifies the secondary or consequential hazards that can occur from the primary event, in turn creating 'compound extremes'. A compound extreme is defined as *"the simultaneous or sequential occurrence of multiple extreme events at singular or multiple locations"*.[24]

Compound extremes have the capacity to make the impact of related extreme events worse when compared to the impact of each individual event in isolation.[25] The Victorian bushfires in 2009 and Queensland bushfires in 2018 are clear examples of compound extremes which emerged due to preceding heatwaves.

The following conditions highlight the potential for secondary hazards to emerge during heatwaves and should be considered during any assessment on heatwave risk:

- The increase in sustained elevated temperatures, because of severe and extreme heatwaves, may lead to the greater potential for extreme fire weather (outlined below) from which major bushfires can occur.[26]

> Fire weather is a combination of conditions that sets the stage for the rapid spread of bushfires. These include:
> - maximum temperature
> - minimum relative humidity
> - wind speed
> - wind direction
> - mixing height (the height at which smoke will stop rising).

- Increase in propensity for electrical storms (including dry lightning) due to the prevailing climatic conditions during heatwaves. Dry lightning is one of the main sources of bushfire ignition in Queensland.[27]
- Persistent rainfall deficiencies have led to drought in many parts of Queensland and an increase in potential fire conditions. Heatwaves exacerbate the underlying conditions which may lead to greater economic and livestock losses.[28]
- Recent studies have shown that marine heatwaves can result in greater potential for the development of tropical cyclones (cyclogenesis). While other factors are known to affect tropical cyclogenesis frequency and intensity, the presence of sustained, high sea surface temperatures (>26.5°C) maintains the warm core that fuels tropical systems.[29]
- The potential for heatwaves to exist as a consequential hazard to other major hazards that affect Queensland is important to note. This is explored further in the section Cyclone associated heatwaves on page 24.

The Tinnanbar bushfires, November 2018. Source: Queensland Fire and Emergency Services

Case study: Record temperatures, catastrophic fires – the 2018 Queensland heatwave and bushfires[30]

A broad area heatwave affected the north tropical and central coasts of Queensland from 24 to 30 November 2018. Numerous locations reported the highest daily maximum temperature on record for November, or for any month, with some locations breaking their previous record by a large margin.

A deep low to the east of southern New South Wales directed a warm and dry westerly airflow across Queensland, enabling several days of well above average maximum and minimum temperatures. Extreme heatwave conditions were observed in an area from Lockhart River to Shoalwater Bay on the Capricornia Coast, extending to adjacent inland districts. Strong westerly winds, high temperatures and low humidity brought elevated fire danger. High temperatures became established around the central coast of Queensland from 24 November, with the anomalous warmth extending to the north tropical coast by the 25th.

Extremely hot days exceeding 40°C occurred on 26 November around Cooktown, Cairns, Innisfail, Townsville (Mt Stuart), Proserpine and Mackay (Racecourse). Townsville (Mt Stuart) recorded the highest daily maximum temperature in this event, reaching 45.2°C on the 26th. The anomalous heat was confined to the north tropical coast on the 27th, with both Cairns Aero and Cooktown recording two consecutive days above 42°C on 26 and 27 November.

By 28 November, the heat encompassed an area from around Cooktown, south to Gladstone, with Rockhampton reporting a daily maximum temperature of 44.4°C, and Yeppoon reaching 42.2°C. This was the third day in a row that Cooktown, Cairns and South Johnstone recorded daily temperatures of more than 40°C and the third consecutive day that Proserpine recorded temperatures above 43°C.

By 29 November, the peak of the heat had eased but numerous high daily temperature records were still broken. Temperatures at the Cairns Aero site reached 38.8°C on the 29th. This was the fourth day in a row the site had broken its previous November maximum temperature record.

While overnight records were less common, minimum temperatures were still very much above average, providing no meaningful overnight relief from the heat. Record warm nights for November occurred at Innisfail (28.3°C), South Johnstone (27.9°C) and Collinsville (26.9°C) on 28 November and at Cooktown (28.5°C) and Low Isles Lighthouse (27.8°C) on the 29th.

Heatwave severity

Persistent, high daytime temperatures, combined with very high overnight temperatures, created severe and extreme heatwave conditions over and near the tropical Queensland coast from 23 November. Figure I shows the highest heatwave severity category[31] attained during the event. The areas affected by the extreme heatwave encompassed from around Lockhart River in the far north of Cape York Peninsula to the Capricornia Coast near Yeppoon, extending to tropical inland districts. Most of northern and eastern Queensland experienced a low intensity heatwave during this period, while much of the far north tropical to central coasts, and adjacent inland districts, experienced a severe heatwave.

Figure III: Aftermath of the Stanwell bushfires. Source: Queensland Fire and Emergency Services

Highest Heatwave Severity
23 November to 2 December 2018
Australian Bureau of Meteorology

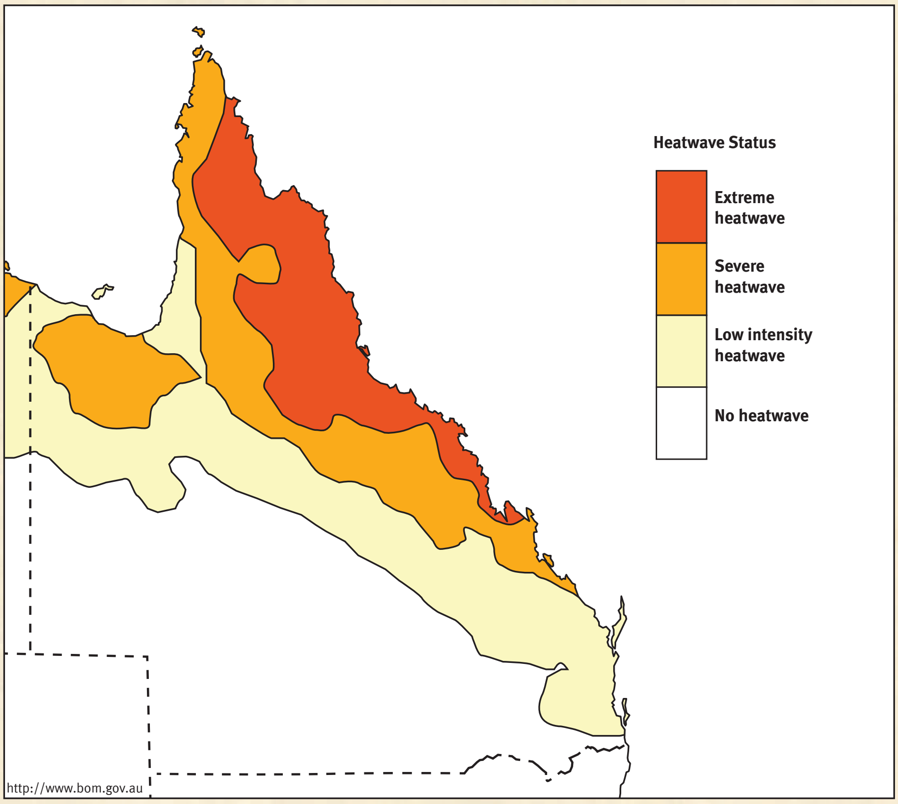


Figure I: Maximum heatwave severity experienced during the November/December heatwaves.
Source: Bureau of Meteorology

Queensland Government

Fire weather and the subsequent bushfires

The 2018-19 fire season in Queensland was extraordinary. The fire weather conditions (elevated temperatures, low humidity and strong westerly winds coupled with recent dry conditions) and fire behaviour that materialised during the bushfire season, particularly during November 2018, had never before been seen in the State at a similar scale. For the first time in Queensland, the Bureau of Meteorology's Forest Fire Danger Index (FFDI)[32] reached over 130 for the Rockhampton area seeing the 'catastrophic' category triggered for several hours in the QFES Central Region. The Commonwealth Scientific and Industry Research Organisation (CSIRO) notes that, "an index of 100 means that fires will burn so fast and hot that control is virtually impossible".[33]

Of note, this was the first time catastrophic levels had been observed in Queensland since the implementation of the revised fire danger rating system in 2010.

Such extreme maximum daytime temperatures and low humidity are typically associated with fire activity in southern states, and this event saw extreme fire weather and bushfires more typical of southern fire prone regions, and less typical of tropical Queensland.

Numerous fires started or flared during the heatwave event. Figure II shows the approximate area burnt between 25 and 30 November. QFES reported about 130 bushfires were being attended to in Queensland by 28 November, with over 716,000 hectares burnt between 26 and 30 November.[34] On 30 November, 105 fires were still burning and by 6 December, over one million hectares had been burnt.

Up to 800 residents of Deepwater were urged to evacuate on 26 November and, on the 28th, around 4,000 residents of Gracemere were evacuated. QFES, with the assistance of the Queensland Reconstruction Authority (QRA), undertook damage assessments in 35 suburbs across eight local government areas (Central Highlands, Gladstone, Isaac, Livingstone, Mackay, Rockhampton, Whitsunday and Cassowary Coast). Nine dwellings were identified as destroyed and an additional eight damaged, along with dozens of sheds and other structures. Various degrees of damage to crops, horticulture and livestock were also noted.

Authored by Community Resilience and Risk Mitigation Branch, Queensland Fire and Emergency Services

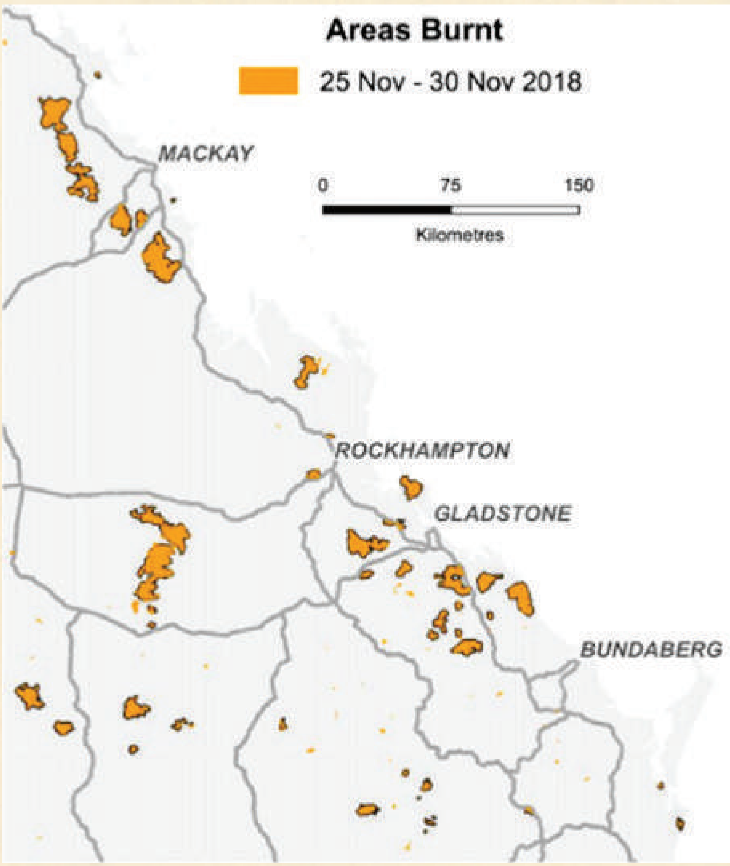


Figure II: Some of the areas burnt between 25 and 30 November 2018, based on a combination of satellite data and aerial surveys. Source: Queensland Fire and Emergency Services

The Queensland context

Since 1958, there has been an observable increase in the occurrence rates of all heatwave severities. Through the BoM's Heatwave Service, the geographic distribution of these changes can be mapped, see Figure 6 below, demonstrating the variability of these changes across Queensland. Between the 30 years 1986 to 2015, a substantial proportion of the State has experienced an average of three heatwave events per year.[35]

This change in heatwave climatology correlates with an increase in demand for heatwave services experienced since the beginning of the 21st century. Queensland Health (QH) has recognised this increased demand and has included heatwave planning since the 2004 Brisbane Heatwave. These plans have been recently aligned with the BoM's Heatwave Service[36] to ensure consistent definitions and public messaging.

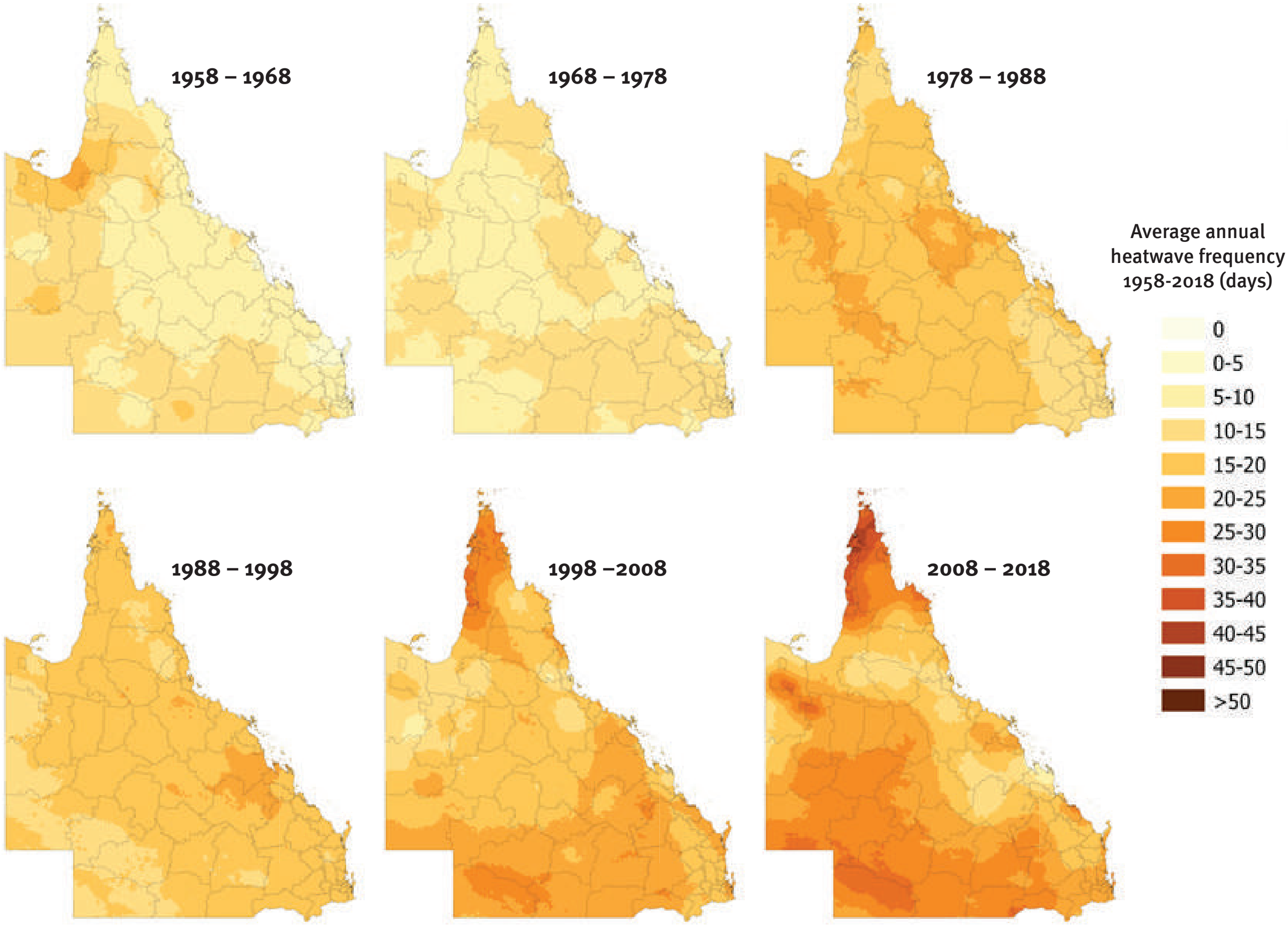


Figure 6: Historical heatwave frequency counts by decade, 1958-2018. Source: Queensland Fire and Emergency Services using data supplied under license by the Bureau of Meteorology

Due to the November heatwave and subsequent bushfires, 2018 brought in to focus the need for greater consideration of heatwave associated risk within the broader disaster management community across Queensland. Numerous locations reported their highest daily maximum temperature on record during November 2018, or for any month, with some locations breaking their previous record by a large margin.[37]

As previously discussed, climate projections show that extreme heat events are expected to occur more often and with greater intensity in the future. This is discussed in further detail within the section on climate change impacts on heatwaves within Queensland on page 28.

Case study: Hotter than ever – the Cairns extreme heatwave

For four consecutive days in late November 2018 – 25 to 29 November – temperatures soared to above 42°C in the centre of Cairns, the highest temperatures recorded in the region,[38] as shown in Figure I. Hot, sticky conditions continued into ensuing days, all just as the BoM had predicted and warned at a Local Disaster Management Group meeting a fortnight earlier.

Comparison of Heatwave Temperatures across Cairns

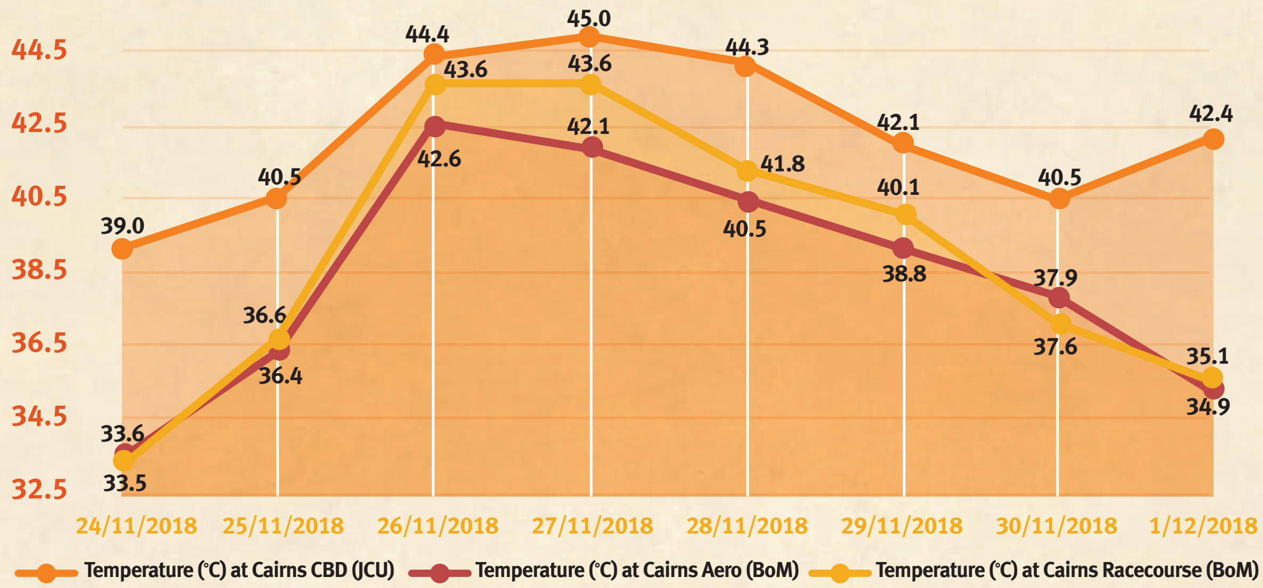


Figure I: Comparison of the highest recorded temperatures within the CBD by James Cook University with those recorded at Cairns Airport by the Bureau of Meteorology. Data provided by Cairns Regional Council

Water restrictions were already in place and the region was on high alert for bushfires. Calls for assistance with failed air conditioning, due to unit failure and single loss of supply faults (blown fuses), persisted throughout the event.

In an area supposedly used to the heat, this was a much different challenge. At least 11 dogs perished because of heatstroke and thousands of spectacled flying foxes fell from their roosts, unable to withstand the temperatures and dry conditions. Groups of deeply concerned citizens and wildlife carers converged at the roost sites, trying to provide distressed animals with life-giving water, arrange for recommended water sprinkling systems to be established, care for survivors and collect the rapidly decomposing dead animals. Fears at a community level divided between humans contracting disease and the long-term survival of the flying fox colonies.

This unprecedented event – characterised by substantial human physical and mental health impacts, destruction of one-third of the Cairns flying fox population (about 23,000 bats), damage to infrastructure, and the adverse effects of very hot weather on the wider population – required a multi-pronged, multi-disciplined, coordinated response.

To address this, the Cairns Local Disaster Management Group has established a new BoM Special Weather Forecast Working Group to provide an effective management bridge between more traditional hazards and 'other' weather events associated with BoM services.

Figure II: The collection of flying foxes which succumbed to the effects of the extreme heatwave forced some residents to be evacuated from their homes due to potential human health impacts. Source: Cairns Local Disaster Management Group

Authored by Cairns Local Disaster Management Group

Following the Cairns extreme heatwave, as outlined in the preceding case study, a review conducted by Queensland Ambulance Service (QAS) performance during the Queensland bushfires and Heatwave Post Incident Analysis (PIA) identified notable increases in people affected by extreme heat.

During the period 25 to 30 November 2018, Cairns and Hinterland Local Ambulance Service Network (LASN) attended a total of 21 requests for service for patients presenting with heatwave related symptoms. A comparative analysis of previous years during the same period showed that Cairns and Hinterland LASN responded to one request for service in 2017 and three requests for service in 2016.

Within the period of the afternoon of 28 November to the morning of 5 December, Cairns and Hinterland Hospital and Health Service reported 49 patients had either been transported to hospital or presented with symptoms related to heat stress (exhaustion) and stroke. The peak of presentations was observed during 28 November when the temperature reached 42.2°C in Cairns. By the morning of 29 November, 31 patients had been treated by Cairns Hospital and QAS with symptoms related to heat stroke.[39]

While official heatwave conditions eased on 30 November 2018, significantly higher than average temperatures and associated conditions persisted for much of December 2018.

A review of the statistics for the whole of December 2018 showed that the Cairns and Hinterland LASN attended 23 requests for service for patients presenting with heat stress related symptoms. A comparative analysis of previous years during December indicated that Cairns and Hinterland LASN responded to 10 requests for service in 2017 and just six requests for service in 2016.[40] This highlights that those heat events which may not be officially declared as a heatwave still warrant the same consideration in terms of potential impact.

To identify future mitigation strategies against increasing heat risk within the Cairns central business district, James Cook University (JCU) is working with the Cairns Regional Council to record temperature and humidity within the urban environment. Using a network of 75 real-time sensors, JCU and the council will map and analyse people's experience of living and working within the CBD (Figure III below).[41] The results of this study will enable Cairns Regional Council to understand and communicate its heatwave risk and strengthen its urban planning and design. This project will be completed in May 2020. At the time of writing, JCU was investigating other potential case study areas.

Authored by Queensland Ambulance Service and Cairns Regional Council

Heat exhaustion: Occurs when a person's body temperature rises above 37 degrees but below 40 degrees Celsius.

Heat Stroke: The most serious form of heat-related illnesses, with a body temperature higher than 40 degrees Celsius.

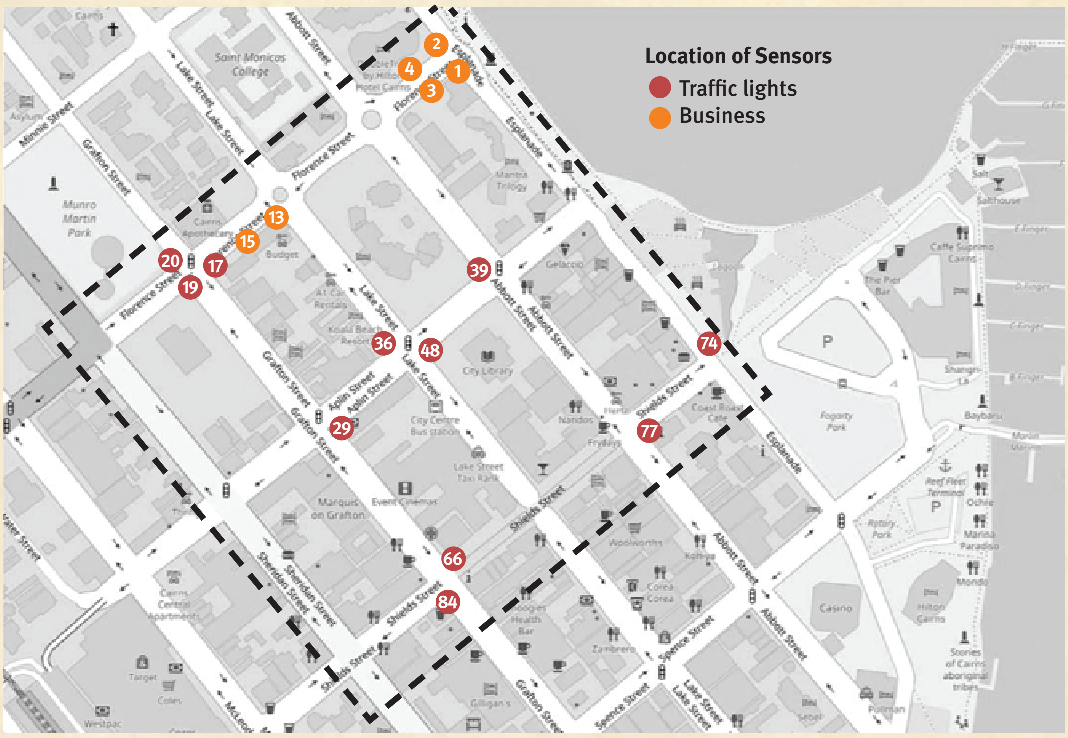


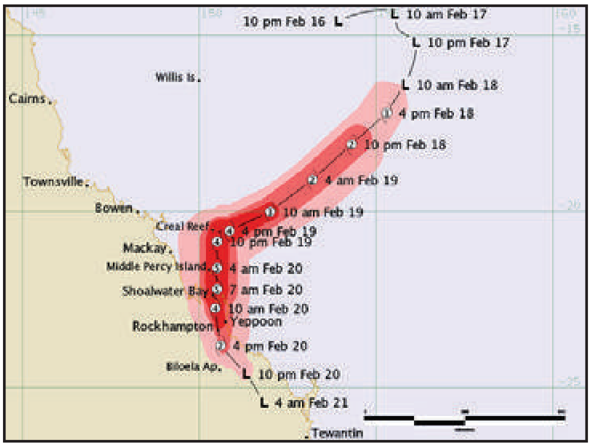
Figure III: Location of temperature and humidity sensors within Cairns CBD which returned verified temperature readings during the Cairns extreme heatwave. Source: James Cook University

Cyclone associated heatwaves

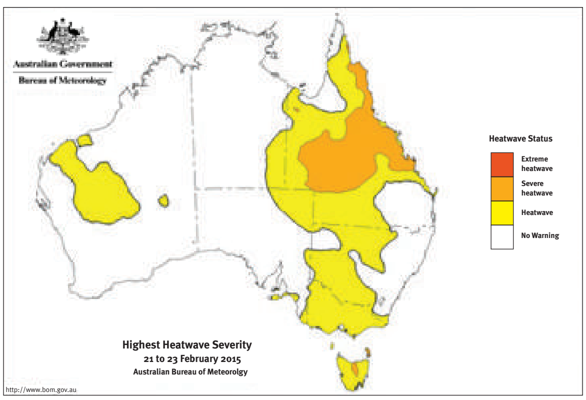
Heatwaves are not often considered in the same context as other severe weather events such as tropical cyclones. However, observations of the climatic conditions in the aftermath of events such as Severe Tropical Cyclone Yasi in 2011, ex-Tropical Cyclone Oswald in 2013 and Severe Tropical Cyclone Marcia in 2015 have shown that extreme heat events have occurred within the regions on the western or northern side of tropical cyclones.[42]

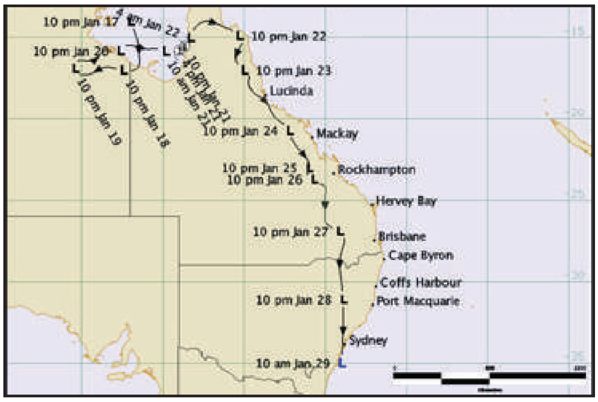
For example, Cardwell's hottest night on record occurred on 28 March 2017 during the approach of Severe Topical Cyclone Debbie to coastal areas further south.[43] As cyclones traverse the State, they can generate the conditions necessary for severe and extreme heatwaves across a broad area. This is explored further within the case study (page 25) on the impact to the Rockhampton and Gladstone regions following Severe Tropical Cyclone Marcia. While this link between cyclones and heatwaves may have been present throughout history, the study of this phenomenon is only relatively recent.

The cause of these cyclone associated heatwaves is thought to be due to those areas in the wake of westward or southward travelling cyclones/tropical lows experiencing a process known as advection. Advection is the horizontal, bulk transport of some property of the atmosphere or ocean into another area. In this instance, what is transported by these cyclones in their west/south-westerly track is an air mass from the central regions of Australia which are much drier and hotter than normal (for the tropics).[44]

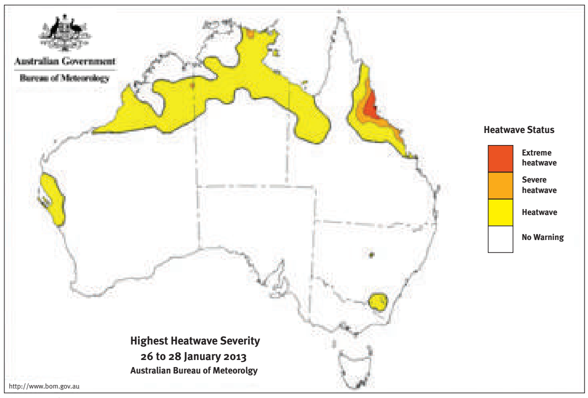


Figures 7 & 8: The track of Severe Tropical Cyclone Marcia and the corresponding heatwave across a large area of northern and Central Queensland. Source: Bureau of Meteorology





Figures 9 & 10: The track of ex-Tropical Cyclone Oswald and the corresponding heatwaves which occurred across a large area of northern Queensland. The heatwave severity was much higher between Cairns and Townsville where the path of the low came close to the coast. Source: Bureau of Meteorology



Tropical regions of Queensland cannot generate the high in situ temperatures normal for those areas within the dry interior of Australia. As this very dry and hot air mass moves into the tropics, it quickly gathers humidity from the underlying moist tropical land mass, building higher humidity in a very shallow layer (where we live). This transported air mass may not be as humid as that within the cyclone or tropical low (which brings rain). However, the conditions experienced by those in the wake of the cyclone will be extremely uncomfortable because of much higher temperatures, which are experienced for a considerable portion of the day and night due to the turbulent mixing of the surface environment.[45]

The heatwave severity maps and associated cyclone track maps (Figures 7 to 10) demonstrate the relationship between the progression of the cyclones and the heat events that followed immediately after.

Understanding this link between cyclones and heatwaves is critical in determining the vulnerability of people, systems and structures because these heatwaves may occur in the aftermath of direct cyclone impact. This is especially important when we consider that directly affected areas may have suffered extensive community impacts, infrastructure damage, loss of power and water, and other essential amenities.

The compounding effect of these two hazards may not have been considered within previous risk assessments, and disaster management and business continuity plans. The case study on the severe heat event following Severe Tropical Cyclone Marcia on page 25, provides a good example of important considerations for the disaster management community when planning or responding to these events.

Case study: Increased stress from heat – health and wellbeing post-Severe Tropical Cyclone Marcia

Event timeline

Severe Tropical Cyclone (STC) Marcia was officially designated a Category 1 tropical cyclone on the evening of 18 February 2015. The system then rapidly intensified to Category 4 over the next 10 or so hours. By 20 February, STC Marcia had intensified to Category 5, crossing the Queensland coast at a largely uninhabited area at Shoalwater Bay, 90 kilometres north-north-west of Yeppoon, at 8.00 am.[46]

STC Marcia was a relatively compact system, which weakened quickly as it moved over land. It is believed only a small part of coastline within about 15 kilometres of the centre would have experienced Category 5 strength winds. The township of Yeppoon received considerable damage, experiencing the equivalent of a Category 3 system, as the Category 4 centre of STC Marcia passed to the west.[47] At 11.30am on 20 February, Ergon reported 11,000 homes without power in the Yeppoon area.[48]

The eye of STC Marcia then passed over Rockhampton, which experienced winds of high-end Category 2 strength.[49] More than 2,000 power lines were downed by trees and debris, and supply to Ergon's primary zone substations was affected. Approximately 65,000 residents in Rockhampton were left without power, and 97 per cent of Rockhampton and 100 per cent of Capricorn Coast residents were affected by power outages.[50] Only half of all customers had power restored by Thursday, 26 February.[51]

A severe heat event leading to significantly above average temperatures and humid conditions was experienced in Rockhampton and Yeppoon post impact, as shown in Figure I below. Compounded by a lack of power to provide cooling and refrigeration, these conditions may have contributed to a spike of heat-related health and wellbeing conditions, significantly increased calls for ambulance services and presentations to local emergency departments.

DAILY TEMPERATURE FOR FEBRUARY 2015

BoM Station	17	18	19	20	21	22	23	24	25	26	27	28
Rosslyn Bay NTC AWS	27.2	27.3	27.1	27.6						29.1	29.5	29.6
033208	23.3	21.9	22.8	23.1	24.3	25.7				23.5	25.6	26.3
Yeppoon The Esplanade	28.7	28.3	27.1	28.3				29.8	30.2	29.3	30.2	29.7
033294	22.2	21.3	23.5	23.2	23.9			24.8	23.1	23.1	24.5	23.7
Samuel Hill Aero	28.4	28.7	26.1									
033308	22.1	21.1	23.3	22.5								
Rockhampton Aero	30.5	27.9	26.7	28.0	35.2	36.8	34.7	32.7	32.5	32.0	31.2	31.8
039083	21.0	20.1	21.4	22.7	23.9	24.9	26.4	24.8	23.7	22.3	23.7	22.3
Gladstone Radar	31.1	28.1	25.9	25.9	32.7	35.9	32.8	32.1	33.5	32.4	32.5	32.4
039123	21.7	21.2	23.1	22.5	23.6	24.2	24.4	23.5	22.9	22.3	23.8	23.4
Rundle Island	26.9	27.0	27.0	27.1	32.0	30.1	29.0	28.1	27.8	28.4	28.5	28.8
039322	23.4	22.3	23.8	23.0	24.7	25.2	26.2	25.0	24.5	24.0	25.4	25.7
Gladstone Airport	30.2	29.8	26.6	27.0	32.7	36.5	32.3	32.8	32.6	30.6	30.2	31.2
039326	22.6	21.3	23.7	23.3	24.2	24.7	25.4	23.4	22.6	22.0	24.1	22.3

Maximum Air Temperature (°C)

Minimum Air Temperature (°C)

MARCIA IMPACT

5 to 6° ABOVE AVERAGE

LOSS OF POWER

HEAT EVENT

Figure I: Temperature records for the Livingstone, Rockhampton and Gladstone areas during the days immediately pre- and post-STC Marcia's impact. Blank cells indicate loss of telemetry from these stations during this period. The records indicate the possible presence of a severe heatwave with significantly elevated temperatures from 21 to 24 February 2015. Source: Bureau of Meteorology

Health impacts

The Queensland Ambulance Service (QAS) Emergency Management Unit conducted a de-identified case review of QAS Communication Centre incidents for the period 18 to 28 February 2015 to quantify first responses to heat-related health and wellbeing issues. Data also was sourced for the same timeframe in comparison years 2014 and 2016. The search focused on the term 'heat related' in call records for incidents during the close lead up to, or in days immediately post impact of, STC Marcia on Yeppoon and Rockhampton.[52]

The QAS review identified 25 heat-related incidents across the study period in 2015, with the majority of these (17, or 68%) being within the three days immediately post impact (21 to 23 February). When compared with the comparison years, there was only one heat-related case identified in the preceding year (2014) and no heat-related cases in the following year (2016).

The identified incidents occurred due to exertion or exercise while exposed to the heat, or the inability of vulnerable patients to access air conditioning due to lack of electricity. Common signs and symptoms identified through this process included:

- feeling dry
- nausea, vomiting, feeling lightheaded, experiencing dizziness, or fainting
- feeling lethargic, weak or generally unwell.

The Central Queensland Hospital and Health Service also provided data on Emergency Department presentations to Rockhampton and Capricorn Coast (Yeppoon) hospitals for the timeframe 18 to 28 February for the years 2014, 2015 and 2016. While the days immediately prior to, and the day of, impact showed decreased presentations at both sites, the days immediately following showed a notable increase, which then normalised over a six day period (21 to 26 February).

This peaked on 22 February with 230 presentations for Rockhampton and 98 presentations for Capricorn Coast. The mean daily presentations for the study period increased from 139 (2014) and 133 (2016) to 176.

Figure II shows a graphic representation of daily presentations for Rockhampton Hospital across the study period in 2015 and the comparison years of 2014 and 2016. When compared to the average daily presentations for 2014 and 2016 (combined), for the three days immediately post impact, 2015 presentations increased by 41 per cent on 21 February (n = 199), 58 per cent on 22 February (n = 230) and 56 per cent on 23 February (n = 183). Following these three days, numbers reduced to slightly higher than average, before normalising six days post-event.

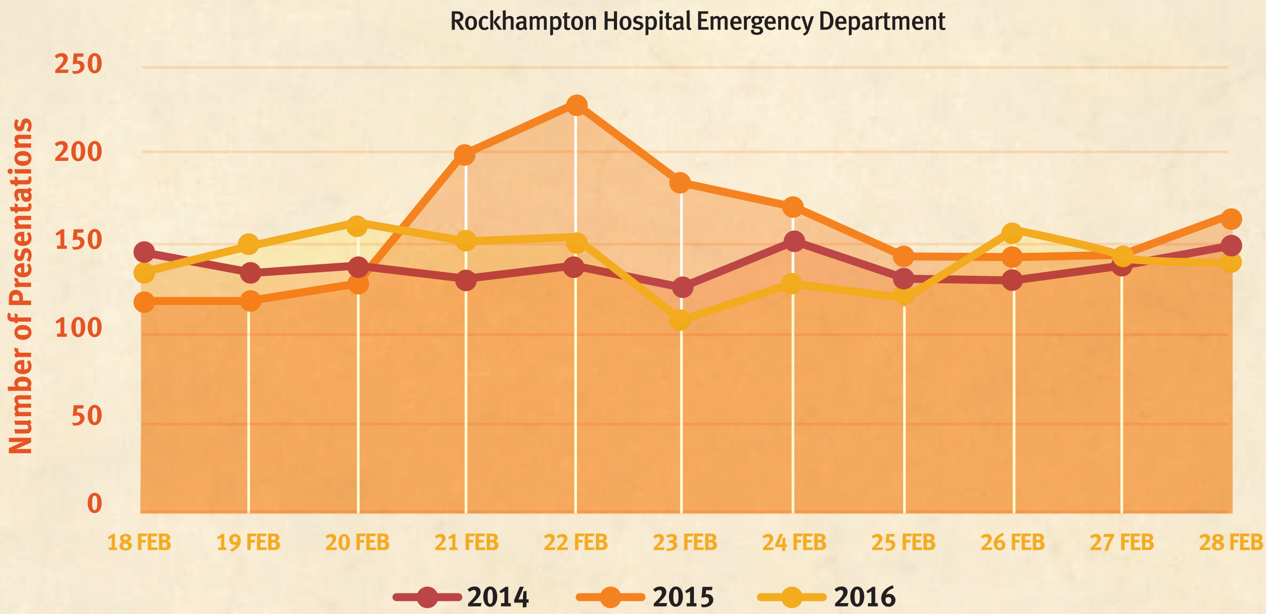


Figure II: Rockhampton Hospital Emergency Department presentations for the period 18 to 28 February 2014 to 2016. Source: Queensland Health

Figure III shows the daily presentations across the same data timeframes for the Capricorn Coast Hospital. Interestingly, the presentation spike for Yeppoon lasted longer and was more prominent at its peak than Rockhampton, with above average presentations staying slightly higher to the end of the data period. When compared to the combined 2014 and 2016 average daily presentations for 21 to 25 February, the 2015 presentation rates were as follows:

- 21 February – 82 presentations (+ 110%)
- 22 February – 98 presentations (+ 172%)
- 23 February – 71 presentations (+ 77%)
- 24 February – 56 presentations (+ 47%)
- 25 February – 57 presentations (+ 111%).

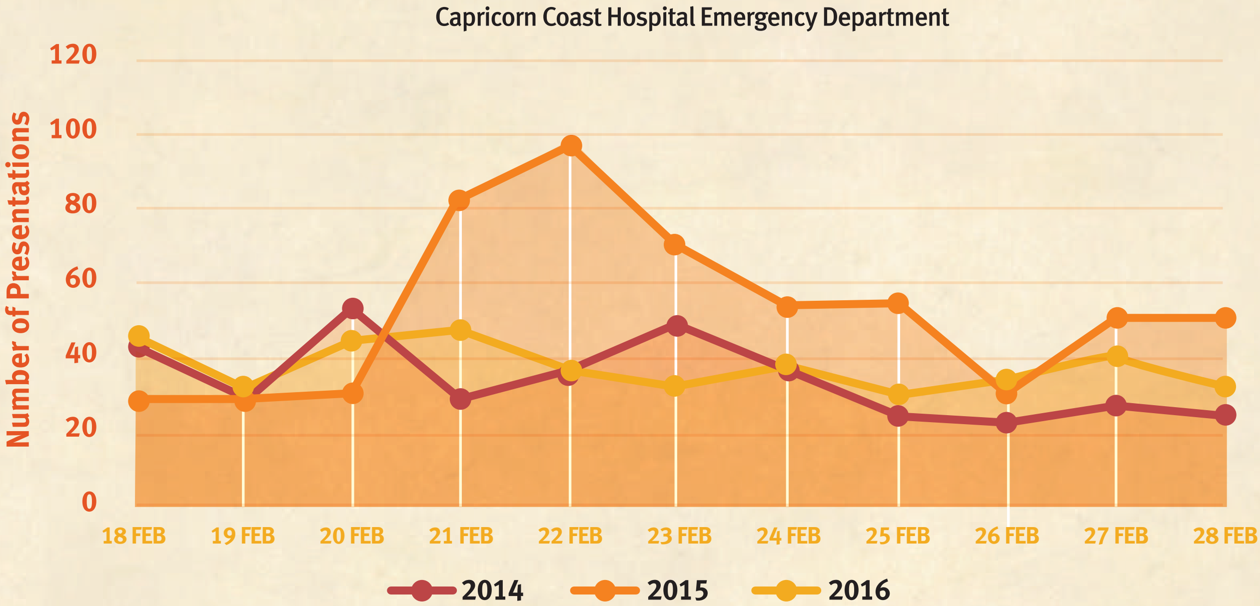


Figure III: Capricorn Coast Hospital Emergency Department presentations for the period 18 to 28 February 2014 to 2016. Source: Queensland Health

Limitations

While increased Emergency Department presentations were experienced in the days post-STC Marcia, the combination of heat and power outages cannot be solely attributable.

Research conducted post-STC Yasi also found an increase in Emergency Department presentations with no specific link to heat or power loss. Although these factors were not specifically examined in this study, it was conducted in a tropical area with an impact in the summer months, with a significant population affected by power outages for up to a week post impact.

Rather, the increases were seen as an amplification of normal attendance patterns.[53] However, anecdotal evidence from a State Heatwave Risk Assessment workshop held in Yeppoon on 18 October 2018 indicated heat and lack of power may have been prominent factors resulting in a general decline in health and wellbeing across both communities.[54]

Authored by Queensland Health Disaster Management Unit and Queensland Ambulance Service Emergency Management Unit, with input from Central Queensland Hospital and Health Service

The impact of climate change on heatwaves in Queensland

Climate change refers to any significant change in the measures of climate lasting for several decades or longer, such as temperature, rainfall or wind patterns.[55] It is different from weather, which is short-term and variable. Climate change is attributed to a number of natural and human induced factors and is ongoing.

The science and wide-ranging impacts of climate change have recently been addressed for Queensland in the Emergency Management Sector Adaptation Plan (EM-SAP) which is part of the Queensland Climate Adaptation Strategy (Q-CAS). For the purposes of this assessment, the impact of climate change will focus on the resulting changes to trends in heatwave frequency, duration and intensity.

Importantly, these trends represent the projected average trend, meaning that changes to climate over time will be experienced unevenly across the State and may vary significantly from the average.[56]

Global and Australian context

The number of record-breaking heat extremes over the past century is now five times higher in comparison to what would be expected without global warming. Globally, both historical records and future projections have shown that heatwaves and warm spells are becoming more frequent and intense, and last longer. The past four years were the four hottest years on record for global surface temperature, continuing a long-term warming trend. Globally, 2018 was the fourth hottest year on record for surface temperature, following 2017 (the third hottest), 2015 (the second hottest) and 2016 (the hottest). In Australia, the surface air temperature for 2018 was 1.14°C above the 1961-1990 average, making 2018 the third hottest year on record. In Australia, nine of the 10 hottest years on record have occurred since 2005.[57]

Heatwave events have become more intense over the 70 year period assessed, with a consistent increase in amplitude, magnitude, frequency and duration across Australia. The increase in heatwave characteristics, as outlined below, varies across Australia, with faster rates of change in Victoria, South Australia, Tasmania and Australian Capital Territory compared to Queensland and the Northern Territory.[58]

The Queensland context

Significant increasing trends have been observed and are predicted for Queensland to the end of the current century. South-west and Central Queensland had a greater rate of increase in heatwave characteristics over the past 70 years than the rest of the State, while future projections indicate a widespread increase.[59]

While the above statement refers to all heatwave intensities, long-term increases in the occurrence of heatwaves classified as severe and extreme have also been observed across large parts of Queensland since the 1940s (see Figure 6 on page 21). Notably, the pace and scale of change has and is escalating with time.[60]

Due to extensive analysis of high resolution temperature data undertaken by the Department and Environment and Science (DES) Climate Science Division, new insights into regionally specific patterns of heatwave changes are now possible, particularly when compared with previous studies. This is explored further within Section 3: The Assessment section of this document (page 30), with high resolution data available for nine community typologies indicative of the diverse communities, economies and climates within Queensland.

In terms of the general Queensland context, the work undertaken by DES has shown that the frequency, duration and intensity of heatwaves will continue to increase over the current century with sharper increases expected after 2050. They are projected to reach unprecedented levels by the end of the century in the absence of strong mitigation measures and significant transformation of the way we live.

Figure 11a shows the projected increase in heatwaves against four of eight heatwave characteristics[63] from 1981 to 2098.[64] These four characteristics are the most indicative of change in heatwave occurrence. These are Duration, Frequency, Temperature of heatwave magnitude, and Temperature of heatwave amplitude, and are explained below. Figure 11b highlights the geographic change in heatwave frequency across Queensland from 2030 to 2090.

Considering the four key characteristics discussed above, under the current projected future climate, by 2090 Queensland may experience:

1. 15 per cent of the year in heatwave conditions, up from 3 per cent in 2018
2. an increase in the duration of individual heatwaves from four days to close to 30 days
3. an increase of the average temperature of all heatwaves from 32.5˚C to 36˚C
4. an increase of the average temperature of all the hottest heatwave days from 34˚C to 43˚C.

Importantly, some region-specific analysis shows a trend of a decreasing number of heatwave events because the duration of individual heatwave events will exceed 120 days. This indicates that parts of Queensland will experience a significant rise in its mean average temperature leading to the heatwave conditions of today becoming the norm in the future (refer to pages 32 and 33).[65]

Index	Heatwave Index	Definition
HWF	Heatwave frequency	Number of heatwave days relative to number of days in an year - i.e. [number of heatwave days/365] x 100 (%)
HWD	Heatwave duration	Number of days of the longest heatwave of the year (days)
HWMt	Temperature of heatwave magnitude	Average mean[61] temperature (in ˚C) of all heatwave days across the year
HWAt	Temperature of heatwave amplitude	Average mean[62] temperature (in ˚C) of the hottest heatwave day of the year

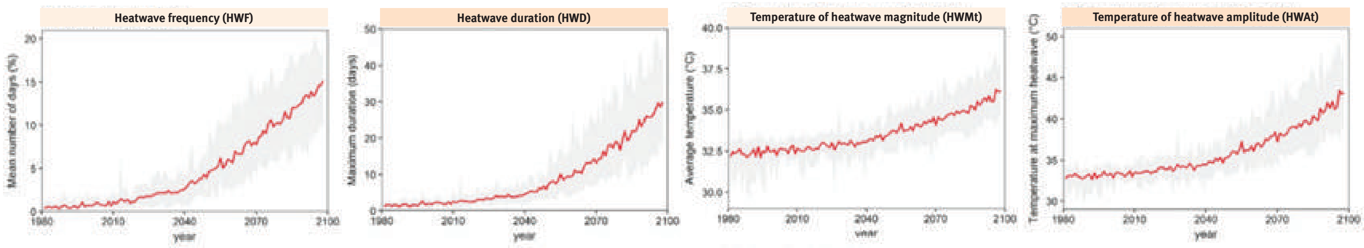


Figure 11a: Projected change in heatwave characteristics within Queensland (1981-2098). Source: Department of Environment and Science

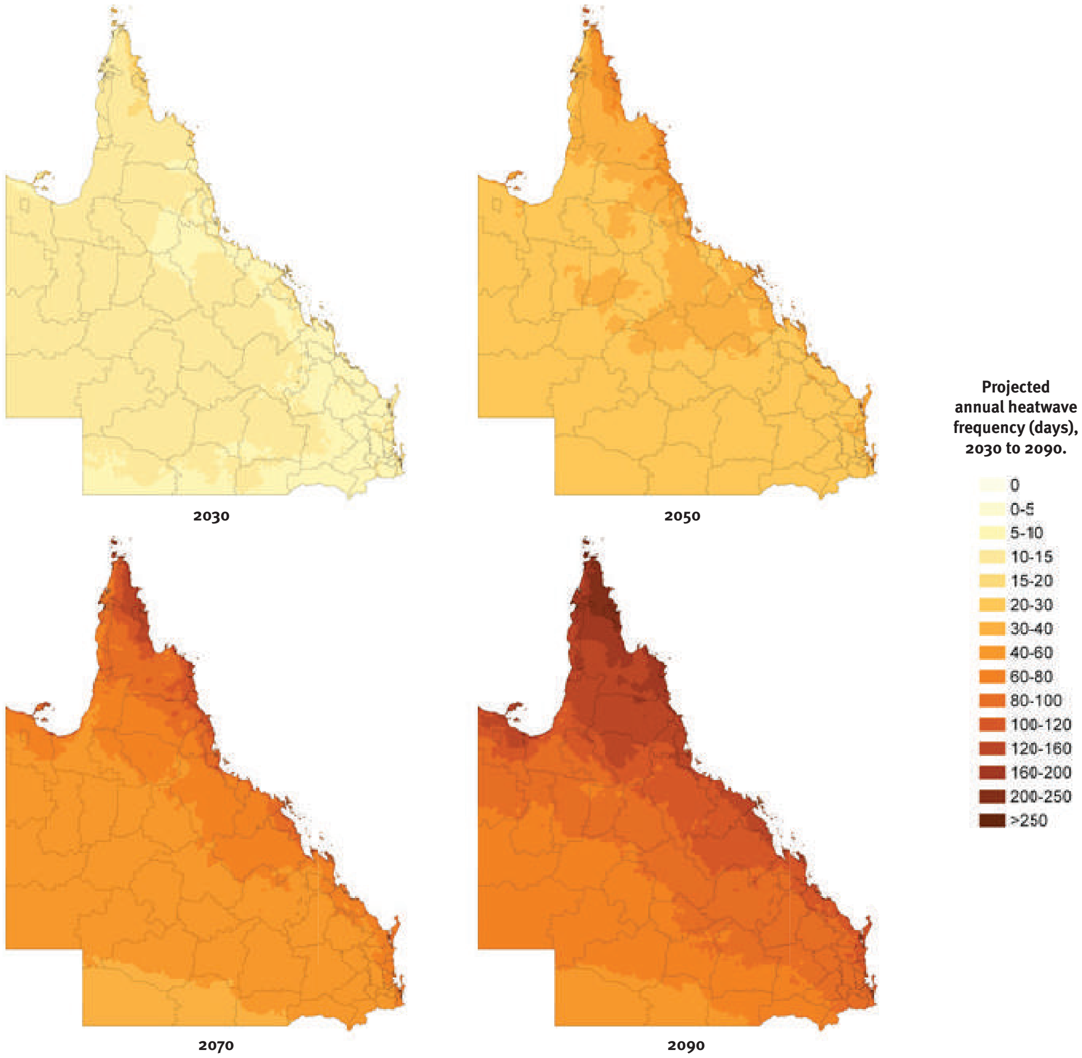


Figure 11b: Projected change in heatwave frequency across Queensland (2030-2090). Produced by Queensland Fire and Emergency Services from data provided by Department of Environment and Science

THE ASSESSMENT

The assessment

Regional assessment of future heatwave occurrence

To better communicate the projected changes in heatwaves across the different climate regions within Queensland, the assessment has selected nine community typologies that are representative of the differences in:

- climatology
- demographics[66]
- social vulnerability (using the Australian Bureau of Statistics' Socio-Economic Indexes for Areas (SEIFA) as a baseline)[67]
- regional economic profiles.[68]

The boundaries selected for this analysis generally follow local government areas (LGAs). However, where LGAs were too small to represent regional climatic processes, they were grouped with adjacent LGAs with similar climate profiles (see Figure 12 below). The Gold Coast is an exception to this rule as the State Heatwave Risk Assessment (SHRA) aims to represent a community indicative of a complex urban environment.

The results of this analysis are shown within the infographic on pages 32 and 33 and have been used to inform the conclusions drawn from this assessment as outlined in Section 6: Summary on page 60.

	REGION NAME	LOCAL GOVERNMENT AREAS
1	Eastern Gulf of Carpentaria	Mapoon Aboriginal Shire Council, Napranum Aboriginal Shire Council, Pormpuraaw Aboriginal Shire Council, Kowanyama Aboriginal Shire Council
2	Mount Isa	Mount Isa City Council
3	Etheridge	Etheridge Shire Council
4	Wet Tropics Coast	Douglas Shire Council, Cairns Regional Council, Cassowary Coast Regional Council
5	Longreach	Longreach Regional Council
6	Mackay	Mackay Regional Council
7	Central Highlands	Central Highland Regional Council
8	Maranoa	Maranoa Regional Council
9	City of Gold Coast	City of Gold Coast

Figure 12: Selected community typologies to present regionalised high-resolution heatwave projections.
Source: Queensland Fire and Emergency Services and Department of Environment and Science

Heatwave projections for selected locations in Queensland (1986 to 2090)

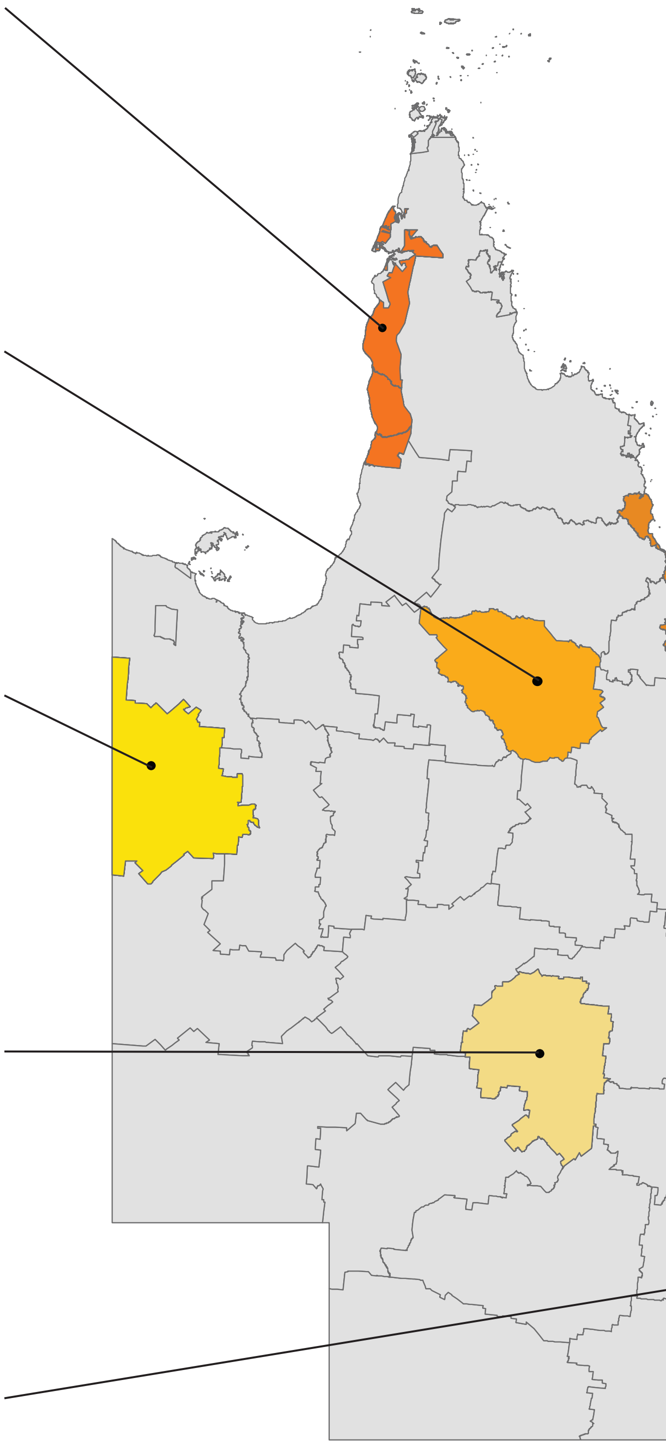
EASTERN GULF OF CARPENTARIA						
Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	0.4%	3.5%	8.8%	23.4%	44.4%
HWD	Heatwave duration (days)	2	6	14	35	62
HWMt	Temperature of heatwave magnitude (°C)	31.6	32.0	32.4	32.9	33.4
HWAt	Temperature of heatwave amplitude (°C)	31.8	32.4	33.1	34.2	35.3
Hot Days	Days >35°C	65	81	99	134	189
Hot Nights	Nights >20°C	253	288	320	347	358

ETHERIDGE						
Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	1.7%	2.9%	8.2%	19.5%	33.0%
HWD	Heatwave duration (days)	4	4	9	23	48
HWMt	Temperature of heatwave magnitude (°C)	31.4	31.8	32.1	32.6	33.0
HWAt	Temperature of heatwave amplitude (°C)	31.8	32.4	33.0	34.0	35.0
Hot Days	Days >35°C	91	112	152	185	213
Hot Nights	Nights >20°C	159	192	224	259	295

MOUNT ISA						
Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	1.6%	3.1%	7.2%	14.7%	22.8%
HWD	Heatwave duration (days)	4	3	7	15	29
HWMt	Temperature of heatwave magnitude (°C)	34.3	34.6	35.0	35.5	36.1
HWAt	Temperature of heatwave amplitude (°C)	34.8	35.3	36.0	37.0	38.2
Hot Days	Days >35°C	148	168	203	223	267
Hot Nights	Nights >20°C	177	203	228	254	284

LONGREACH						
Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	2.3%	3.3%	8.1%	14.5%	21.5%
HWD	Heatwave duration (days)	5	3	8	14	26
HWMt	Temperature of heatwave magnitude (°C)	34.1	34.3	34.8	35.2	35.7
HWAt	Temperature of heatwave amplitude (°C)	34.9	35.4	36.1	37.0	38.2
Hot Days	Days >35°C	123	145	171	192	217
Hot Nights	Nights >20°C	133	163	189	217	240

MARANOA						
Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	2.5%	2.8%	7.6%	14.0%	22.3%
HWD	Heatwave duration (days)	5	3	7	12	23
HWMt	Temperature of heatwave magnitude (°C)	31.0	31.3	31.7	32.1	32.5
HWAt	Temperature of heatwave amplitude (°C)	31.9	32.4	33.1	34.0	34.8
Hot Days	Days >35°C	46	54	76	81	98
Hot Nights	Nights >20°C	60	93	122	154	182



UNDERSTANDING THE DATA

Index	Heatwave Index	Definition
HWF	Heatwave frequency	Number of heatwave days relative to number of days in a year - i.e. [number of heatwave days/365] x 100 (%)
HWD	Heatwave duration	Number of days of the longest heatwave of the year (days)
HWMt	Temperature of heatwave magnitude	Average mean temperature (in °C) of all heatwave days across the year
HWAt	Temperature of heatwave amplitude	Average mean temperature (in °C) of the hottest heatwave days of the year
Hot Days	Days >35°C	Annual count of days with maximum temperature >35°C
Hot Nights	Nights >20°C	Annual count of nights with minimum temperature >20°C

Note: All figures represent an absolute change from the reference period (1986 to 2005) unless expressed in negative terms, based on RCP 8.5. Further information and guidance on the data represented within this infographic can be found at Appendix F.

WET TROPICS COAST

Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	1.4%	3.1%	12.5%	29.5%	41.6%
HWD	Heatwave duration (days)	3	4	15	44	80
HWMt	Temperature of heatwave magnitude (°C)	29.2	29.4	29.7	30.3	30.9
HWAt	Temperature of heatwave amplitude (°C)	29.6	29.9	30.6	31.6	32.8
Hot Days	Days >35°C	3	4	17	35	72
Hot Nights	Nights >20°C	179	217	253	289	321

MACKAY

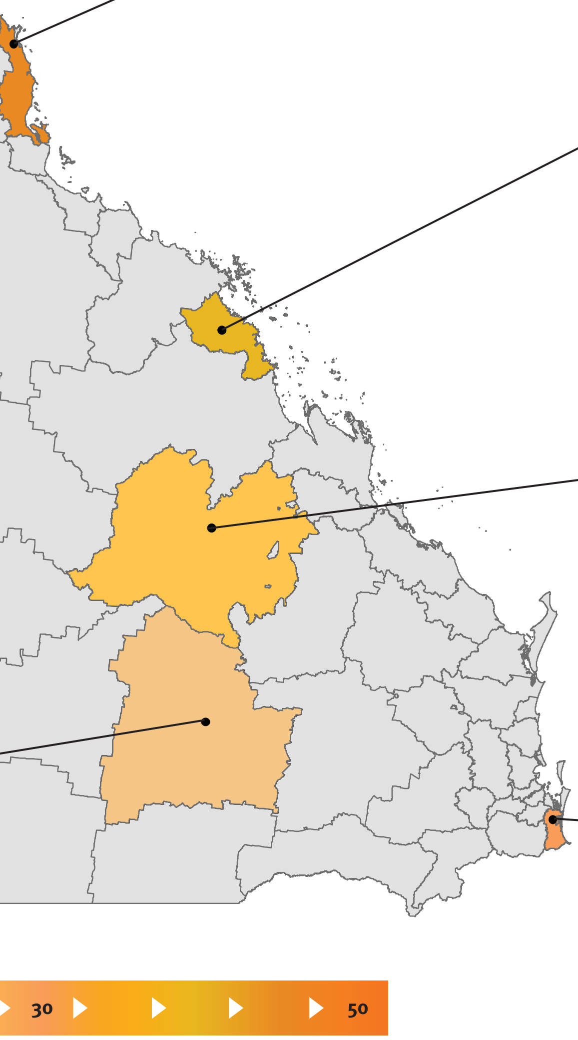
Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	2.1%	3.2%	10.6%	24.3%	35.8%
HWD	Heatwave duration (days)	4	4	11	34	72
HWMt	Temperature of heatwave magnitude (°C)	29.0	29.3	29.7	30.2	30.7
HWAt	Temperature of heatwave amplitude (°C)	29.5	30.0	30.6	31.6	32.8
Hot Days	Days >35°C	4	9	20	33	67
Hot Nights	Nights >20°C	128	157	186	217	255

CENTRAL HIGHLANDS

Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	2.7%	3.0%	8.1%	16.3%	26.5%
HWD	Heatwave duration (days)	5	3	7	16	33
HWMt	Temperature of heatwave magnitude (°C)	30.9	31.3	31.7	32.2	32.7
HWAt	Temperature of heatwave amplitude (°C)	31.8	32.4	33.2	34.2	35.3
Hot Days	Days >35°C	50	62	85	95	117
Hot Nights	Nights >20°C	86	117	146	178	206

CITY OF GOLD COAST

Index	Heatwave Index	Reference	2030	2050	2070	2090
HWF	Heatwave frequency (%)	2.1%	3.1%	8.9%	18.4%	28.4%
HWD	Heatwave duration (days)	4	4	9	22	45
HWMt	Temperature of heatwave magnitude (°C)	27.4	27.7	28.1	28.7	29.1
HWAt	Temperature of heatwave amplitude (°C)	28.4	28.9	29.7	30.7	31.6
Hot Days	Days >35°C	1	3	6	13	34
Hot Nights	Nights >20°C	50	76	106	141	175



Infographic created by Queensland Fire and Emergency Services. Data supplied by the Climate Science Division, Department of Environment and Science

Potential exposures

While heatwaves of all intensities have direct impacts on mortality and morbidity, they also cause numerous indirect impacts to communities. These include stress on electricity networks, emergency services, hospitals and infrastructure, such as road damage and transport delays when railway lines buckle. The impacts of severe and extreme heatwaves are likely to affect all sectors of Queensland's communities, from the public heatwaves. This is because people, infrastructure and the environment typically have the capacity to cope during more common, low intensity heatwaves.

This assessment is applicable for the whole of Queensland, but should be applied and tailored at a local level by considering the increase in heatwave frequencies as outlined in Appendix A.

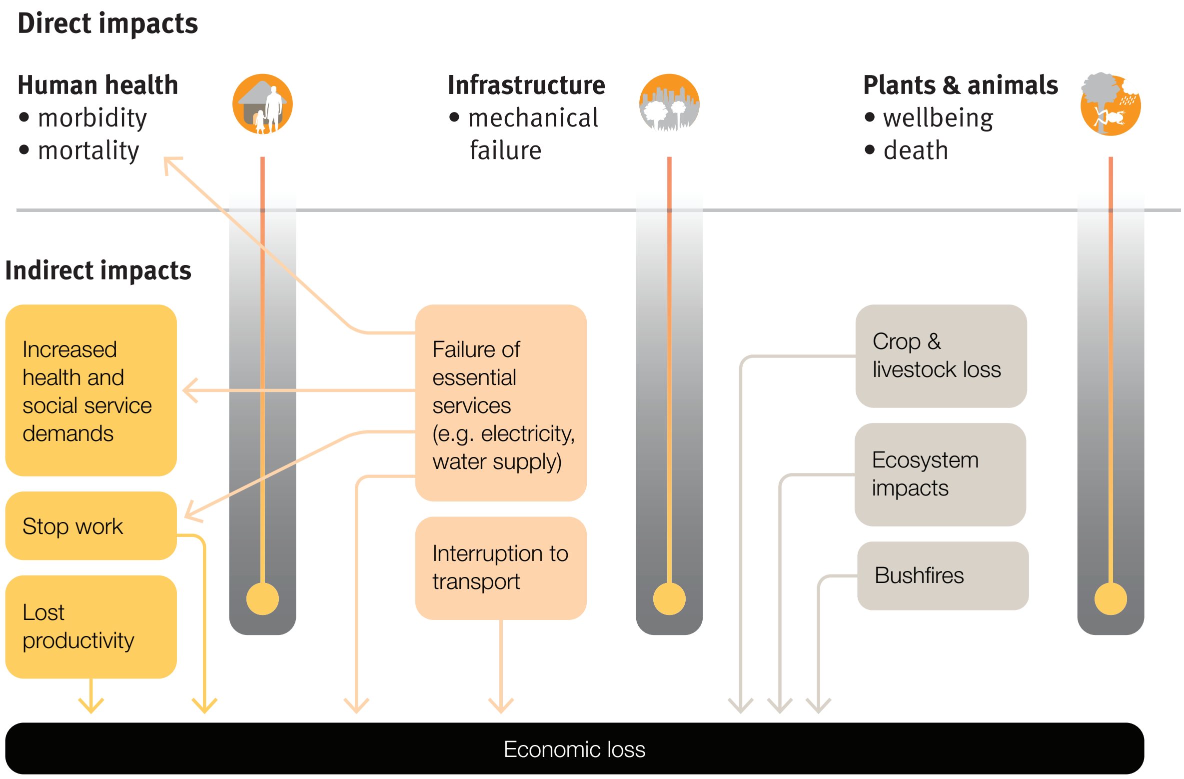


Figure 13: Schematic diagram showing the direct and indirect impacts of extreme heat. Source: NCCARF

to government organisations and industries, health, utilities, commerce, agriculture, and infrastructure (as shown in Figure 13). The impacts that may be currently expected, and which may intensify with the projected increase in frequency, intensity and duration of heatwaves, are explored in greater detail within this section.

Assessing hazard interaction and the impact of hazard characteristics on exposed elements provides a clear understanding of a region's or community's vulnerabilities. This risk assessment highlights those elements susceptible to the characteristics of the hazard under the current and the projected future climate.

For the purposes of this report, the impact has been assessed against the occurrence of severe and extreme intensity

The key observations for communities across Queensland are presented below according to the six exposed element categories outlined within the Queensland Emergency Risk Management Framework (QERMF).

This list is not exhaustive and all the elements highlighted will not be applicable to every local government area (LGA) within Queensland.

Essential infrastructure

Power

- Operational demand on the Queensland transmission network ('the grid') during heatwaves and isolated hot days is increasing year on year. Demand from the grid exceeded 10,000MW for the first time on 11 February 2019.[69] With heatwave events projected to increase in frequency, duration and intensity, demand on the grid is expected to significantly increase.[70]
- Despite the above, it should be noted that Queensland is unlikely to experience a State-wide blackout during severe and extreme heat events.[71]
- Increased presence of rooftop solar is assisting to mitigate impacts to electricity supply during peak demand periods.[72] However, uptake of solar power and decommissioning of non-renewable power stations is resulting in peak demand shifting to later in the evening. Projected increases in the number of hot nights will likely place a strain on power supply later in the evening.[73]
- There are three main types of power interruptions that can occur during a heatwave:[74]
  - Localised outages – impacting a few to several thousand households, these occur due to multiple factors and are likely to result in short-term interruption to supply. Single-Wire Earth Return (SWER) lines and older infrastructure across Queensland are vulnerable due to a lack of resilience against sustained high temperatures.
  - Power system disturbance – occurs when a major event disturbs the power system, most frequently caused by a sudden interruption to critical transmission lines. Heatwaves can occur in combination with other hazards, such as bushfire and tropical cyclone. In Queensland, system disturbance can be expected due to smoke causing short circuiting, or severe wind or bushfire damaging transmission lines and infrastructure.
  - Involuntary load shedding – if there is not enough power to meet demand, sections of the grid will be switched off until supply can be restored, or demand reduces, which generally occurs in the evening.
- The likelihood of involuntary load shedding may increase if impacts to the network have been sustained elsewhere, such as loss of transmission lines due to a cyclone or bushfire.[75]
- As temperatures increase, extra power is demanded by air conditioning, and the ability to dissipate heat from parts of the electricity system can become compromised. Continued elevated temperatures at night contribute further to this problem.[76]
- Transformers are less efficient due to elevated temperatures during extreme events, which may lead to over temperature tripping resulting in localised outages where cooling systems have failed. This represents the biggest risk to modern transmission networks.[77]
- Where backup power generation is available, it may still be vulnerable to failure due to design flaws such as failures in the power computer control network, or through the failure of older individual components linked to modern computer control systems.[78]
- Generators without solar shielding have less capacity to generate due to exposure to above optimal operating temperatures. Coupled with increased demand in the event of a power outage, it is expected that generator redundancy will be significantly reduced during a significant heatwave event.[79]

Communications

- No significant risks from heat impact to strategic communications infrastructure have been identified due to the use of air conditioners on larger telecommunications sites.[80]
- Non-strategic sites including roadside cabinets have been designed to suit local environmental conditions coupled with the installation of cooling cabinets on hubs and exchanges. Failure of cooling systems would elevate the risk of infrastructure failure although the likelihood of this is low.[81]
- Any network component failure that is a direct result of heat is managed and prioritised through a business as usual restoration process.[82]
- Telstra and NBN assets are monitored and managed using remote sensing. However, if power fails, the communications network may be impacted with sporadic outages dependent on the level of redundancy available. It is important to note that the efficiency of battery redundancy reduces – by upwards of 50 per cent in extreme cases – during heatwaves.[83]

Water and sewerage

- Increasing evapotranspiration rates (>5% increase by 2050) coupled with decreasing annual rainfall (>3% decrease by 2050) may impact reservoir/dam levels across the State increasing the possibility of 'water-stressed' communities.[84]
- In terms of water security, increased general demand on service should be anticipated, with less resources to meet the demand. Water security depends on an excess of precipitation over evapotranspiration.[85] Future climate projections show significantly less rainfall in the winter and spring indicating less available water and, subsequently, instances of high water stress within regions of Queensland during summer are likely. This stress is likely to be elevated during severe and extreme heat events.
- Sustained elevated temperatures may damage older elements of the infrastructure, with an increased likelihood of water mains failure during sustained heatwave events.[86]
- There is a higher risk of contamination within infrastructure such as reservoirs and bores through increased rates of bacterial growth, such as blue-green algae. This can pose a risk to human health not only through ingestion but also through direct contact with contaminated water.[87]

Transport infrastructure

- Passengers at surface transport hubs and nodes (stations and stops) are vulnerable to heatwave due to a general lack of adequate mechanical cooling and ventilation at these facilities.[88]

Access and resupply

Road and rail

- Sustained periods of intense heat result in damage to the road and rail network and increasing frequency and duration of heatwaves are expected to exacerbate this damage.[89]
- People are less likely to use active transport during hot weather, increasing reliance on the road and rail network.[90] People walking and using active transport are more likely to be exposed to heat, and more vulnerable to heat-related illness.
- In the event a high-level ambient air temperature has been or will be reached or measured as rail temperature, key personnel advise track maintenance coordinators and both areas (in the field and offsite) monitor and regularly assess the conditions. Train speeds (via Network Control Centres) are adjusted accordingly and widespread distribution of the adjustment to electric multiple unit (EMU) and locomotive-propelled train speeds is communicated across the business and applicable stakeholders (see Figure 14).
- Pavement binding begins to fail between 40°C and 45°C. This can result in road closures and affect heavy haulage (especially in western Queensland and the Darling Downs).[91]
- Elevated temperatures and temperature fluctuations can result in premature deterioration or failure of bridges due to stress from thermal expansion and movement. Long-span bridges are most at risk. Concrete structures built prior to 1980 are most vulnerable as they were not designed to withstand higher temperatures and temperature fluctuations.
- Buckling of rail lines can occur in extreme temperatures, resulting in service cancellations or speed reductions for public transport and freight services.[92]
- Increased risk of bushfire during heatwave conditions may lead to disruption of services and damage to road and rail infrastructure.
- Power infrastructure associated with the road and rail network is not as resilient as the modern transmission network. This could cause higher network failure compared to the broader electricity network, and subsequent disruption to transport services.[93]
- Maintenance and response crews may not (based on entity health and safety policies) work in extreme temperatures and may even switch to night time maintenance schedules. This has historically, and may continue to, delay restoration of services where disruption occurs.[94]

RAIL TEMPERATURE	AMBIENT AIR TEMPERATURE	TRACK STRUCTURE	ACTION
55°C	36.6°C	All	Commence hot weather patrols
58°C	38.6°C	Timber	Restrict EMU to 80km/h Restrict all other trains to 60km/h
		Concrete	Restrict all trains to 120km/h
60°C	40°C	Timber	Restrict EMU to 60km/h Restrict all other trains to 40km/h
		Concrete	Restrict all trains to 90km/h
61°C	40.6°C	Timber	Restrict EMU to 60km/h Restrict all other trains to 40km/h
		Concrete	Restrict all trains to 80km/h
63°C	42°C	Timber	Restrict EMU to 40km/h Restrict all other trains to 30km/h
		Concrete	Restrict all trains to 50km/h

Note: For the purpose of this table, track structure of 'timber' shall include timber sleepers, steel sleepers interspersed and on a face as well as composite sleepers.

Figure 14: Rail temperature conversion table for the management of speed restrictions for different materials and environmental conditions. Source: Department of Transport and Main Roads

Aerial transport and resupply

- Extreme temperatures affect the capacity of air transport. As air temperature rises, air density decreases, resulting in less lift generation by aircraft wings. This means that aircraft takeoff weight will be restricted, or that greater takeoff speeds and runway lengths are required to reach adequate climb rates.[95]
- Heavily loaded flights may need to be rescheduled out of the hottest parts of the day.[96]
- Exhaust heat from aircraft engines can ignite surrounding vegetation during extreme heatwaves.

Maritime transport and resupply

- High temperature poses a potential risk for the loading and unloading of volatile substances such as petroleum and gas products.[97]
- Flaring of excess gas during loading may require monitoring to avoid risk, particularly to surrounding communities.[98]
- Employment arrangements may mean that outdoor workers are entitled to stop work during hot weather, which will affect productivity and delay cargo transfers.[99]
- Operation of heavy machinery may damage port yard surfaces, causing surface rutting and heaving.[100]

Community and social

Demographics

- Rural, regional and remote communities are particularly exposed to increasing temperatures and heat events due to the impact of climate change. This will likely result in an increased demand for social support and mental health services, and, at the same time, make it harder to recruit and retain staff in affected areas.[101]
- The Queensland Government Statistician's Office (QGSO) 'Population Projections: Local Government Areas' report indicates significant depopulation is likely to occur west of the Great Dividing Range by 2041.[102] Climate-related factors including heatwaves are playing an increasing role in climate-based migration.[103]
- Social isolation of vulnerable people also presents issues within the community. Some vulnerable people do not understand heatwave risk and may not be informed of support services available. Cultural and linguistic barriers can also exist which increases social isolation and vulnerability to heatwaves.[104]
- Inconsistent messaging regarding impending heatwaves often causes confusion. Provision of services and advice to people by multiple agencies can result in them being contacted numerous times, sometimes with conflicting information.[105]
- Those who have recently migrated to Queensland from areas with significantly different climates are at extreme risk of heatwave exposure, especially those from temperate climates. This risk increases with recent migrants and tourists for whom English is not the primary language and comprehension of key messaging is poor.[106]
- Wealthier individuals and households are better able to cope with heatwaves. This is because these households are more likely to have air conditioning, are better able to afford associated running costs and are more likely to live in more energy-efficient homes.[107]
- Aboriginal and Torres Strait Islander communities are more vulnerable during heatwaves due to general lower state of health relative to the wider community.[108]
- Tourists to Queensland may not be prepared for the extreme climatic conditions in the State, including high temperatures. While heatwaves will affect all people, residents tend to be more accustomed to and better prepared for heatwaves, particularly in terms of taking appropriate action to deal with heat stress.[109]
- Heatwaves as a natural hazard create some of the highest intangible costs to communities across Queensland. These intangible costs are the direct and indirect costs that cannot be easily priced. They include death, injury and impacts on employment, education, community networks, health and wellbeing, and are outlined in greater detail below.[110]

Social infrastructure

- Some sectors of the community do not currently consider heatwaves as a risk or a natural hazard. This creates barriers to accessing resilience funding streams that may assist in the development of heatwave or heat resistant infrastructure.[111]
- Significant variations in temperature should be expected between the urban and natural environments. Large volumes of heat-absorbing (such as pavement, masonry) and heat-reflecting materials (such as glazing) within urban centres, waste heat emissions from vehicles, air conditioning and industry, coupled with a lack of vegetation can result in significant ambient temperature increases in urban environments (refer to Case study: Hot in the city – the urban heat island effect, heatwaves and human health and wellbeing on page 15).
- If Information and Communications Technology (ICT) infrastructure loses cooling, it can rapidly fail due to the heat produced from this equipment, particularly as it is often housed in enclosed rooms.
- The Department of Education does not currently have a heatwave policy for schools. Decisions regarding the closures of schools during heat events or heatwaves is the responsibility of each school's principal.[112]
- Schools in known heat affected areas and regions should provide adequate air conditioning systems to help manage extreme heat events. It has been identified that some schools across the State still do not provide adequate air conditioning systems for pupils and staff with classroom temperatures in extreme events exceeding 40°C.[113]
- University of Sunshine Coast studies have shown that mathematical skills decline above 25°C and reading comprehension declines above 28°C for school aged children.[114]
- Schools within the 'Cooler Schools Zone' (see Figure 15) receive funding from the Queensland Government to provide schools with air conditioning. However, the other zones are showing a significant increase in annualised heatwave potential which may indicate the prevalence of heatwave conditions in these zones in the near future.
- Extreme heat events and/or a lack of air conditioning systems at schools can result in the suspension of the school day if temperatures exceed localised thresholds.[115]

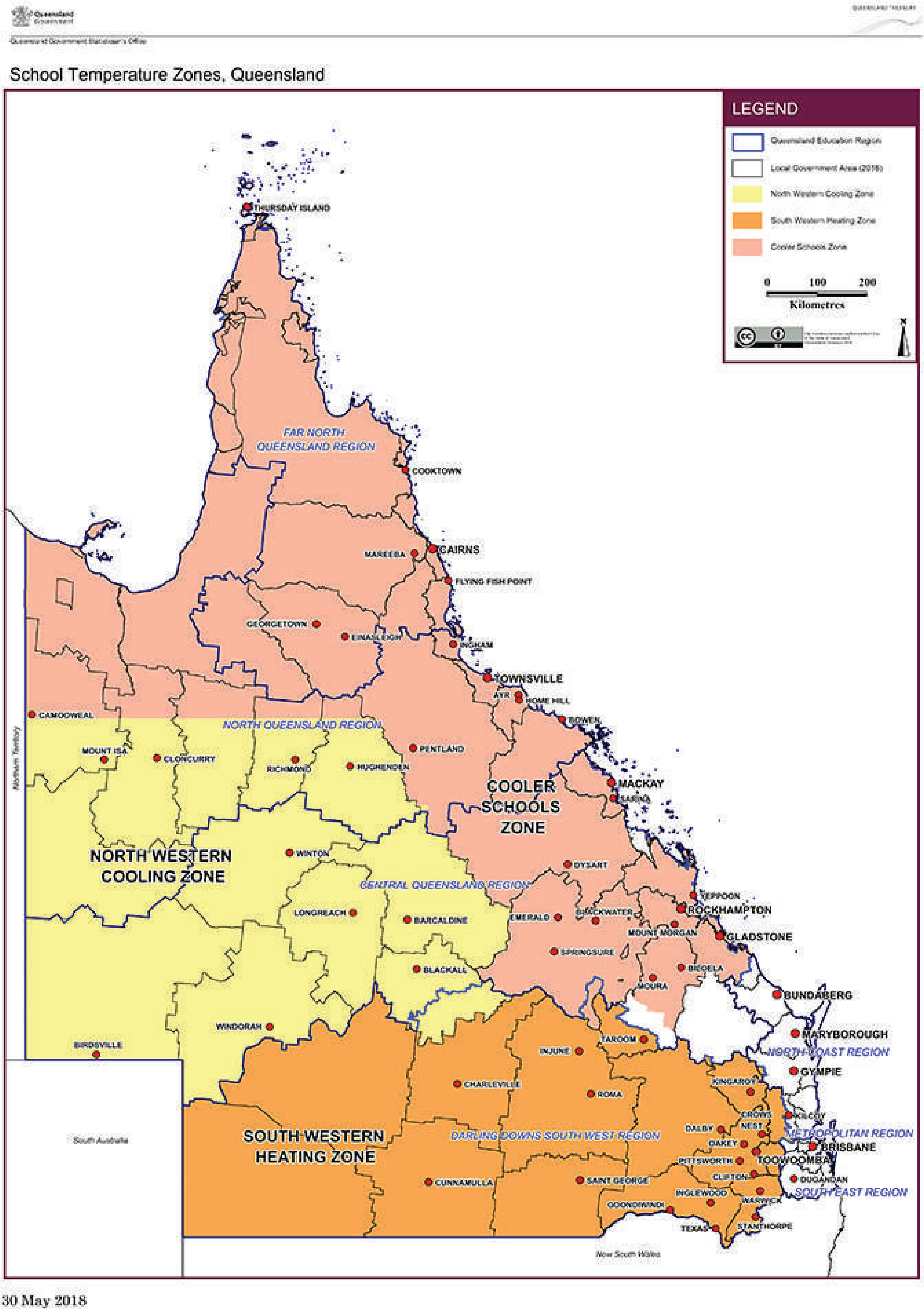


Figure 15: Map of identified School Temperature Zones, showing the Cooler Schools Zone. Source: Queensland Government Statistician's Office

Governance

- Despite the risk to community, high levels of tangible and intangible losses, and connection to other natural disasters such as bushfires, the impacts from severe and extreme heatwaves do not currently fall under the definition of an eligible disaster as outlined within the Natural Disaster Relief and Recovery Arrangements.[116] This lack of associated funding may influence the decision of Local Disaster Management Groups (LDMGs) to activate or not during severe and extreme heatwave events.[117]
- Prioritising liveable and sustainable communities is increasingly reflected in community attitudes. Therefore, the issue of responding to and managing the effects of a changing climate is an increasing concern across Queensland.[118]
- Very few stakeholders involved in consultation for the Human Health and Wellbeing Climate Change Adaptation Plan for Queensland reported any assessment of increasing climate risks for their own facilities, workforce, or services, and only seven per cent of surveyed participants were aware of their legal and financial responsibilities to manage climate risk.[119]
- Recent clarification of legal liability for boards of governance and their directors highlights their fiduciary responsibility to acknowledge climate risks in their strategic and operational plans. This should prompt the evaluation of heatwave related climate risks.[120]
- The risk of financial and corporate liability for not undertaking proactive climate change mitigation and adaptation strategies is increasing. These risks will continue to grow as community understanding of the human health, financial and infrastructure impacts of heatwaves increases. [121]

Building stock

- Building guidelines in Australia use historical analysis of climatic conditions to determine the energy demand of a building and to determine appropriate levels of energy efficiency. These guidelines do not allow for variation in design based on local climatological conditions and are likely to be significantly inadequate for future climatic conditions.[122]
- Australia has seen a trend in increasing housing sizes of European or American design, with an accompanied increase in air conditioning systems and usage. This leads to high electricity consumption charges and greater potential for overload of the electricity grid during heat events.[123]
- Residential and commercial buildings in Australia built prior to 2003 and 2005 respectively were not subject to energy efficiency requirements. These buildings were not subject to mandatory requirements for insulation to reduce heat transfer, increasing vulnerability of occupants to extreme heat events.[124]
- The prohibitive cost of adapting older building stock by either passive or active means of cooling often restricts implementation, while high electricity costs often mean vulnerable groups may not use air conditioning even if available.
- Buildings with large volumes of uninsulated thermal mass (e.g. brick, concrete) significantly increase the vulnerability of occupants to heat-related illness. Buildings with large volumes of insulated thermal mass are more resilient to sudden temperature fluctuations but are vulnerable to protracted heatwaves and take longer to cool down compared to lightweight buildings.[125]
- Air conditioning can fail in extreme heatwaves due to overheating of system components and/or poor maintenance. Contemporary building design does not provide necessary levels of comfort without active means of temperature control and there are no standards in the Building Code to ensure against heat stress. People in these buildings may be less adapted and more vulnerable to heatwave.[126]
- **Refer to the case study at Appendix D: Cooler construction – building design, urban design and urban planning (a guide for Local Government) for further information.**

Emergency management

- Statistics show that the onset of a prolonged or acute heatwave event corresponds to an increase in calls for service from the emergency services, especially from Queensland Ambulance Service, as the risks to human health and other societal risks increase. (Refer to Cairns extreme heatwave case study on page 22.)
- Heatwaves can dramatically increase underlying bushfire risk to potentially extreme levels. During days of extreme fire danger, bushfires can become uncontrollable even if fuel levels are minimal.[127] Any resultant bushfire occurrence would add significant pressure to local and regional emergency management capability and capacity, and increase the risk of impact to the community.
- Climate change and the increasing frequency of heatwave events is increasing the length of fire seasons, which limits the opportunities for prescribed burning.[128] Usual mitigation efforts are less likely to impact bushfires during extreme, and compounding conditions, for example drought, high winds and heatwaves.[129]
- The risk of heat stress and heat stroke for emergency service personnel is managed under operational health and safety guidelines. However, it has been noted that compound extremes, such as simultaneous bushfires and heatwaves, may result in operating thresholds being exceeded faster than normal.[130]

Emergency shelters and places of refuge

- For some people, leaving their home during a heatwave may not be viable due to mobility or transport issues. This may exacerbate their vulnerability, especially for those with pre-existing morbidities. Financial vulnerability may also influence the choice of people to seek cooler places of refuge during heatwaves.[131]
- Public buildings such as shopping centres, libraries, cinemas, and museums may be used by the community as cooler places of refuge. The potential for increased visitation to shopping centres during heatwaves is considered an opportunity by some developers, who are identifying ways to improve the amenity of these spaces during higher temperatures to increase patronage.[132]
- During heatwaves, people tend to migrate to beaches, public pools and inland swimming areas as places of refuge (Figure 16 overleaf). This increases demand on services who monitor these areas, such as lifeguards. It also raises the risks of drowning and injury, exposure to potential injuries from stingers and sharks, and incidents of heat-related stress, especially within the non-resident tourist population. During hot nights, some lifeguards may extend their patrols into the evening or early mornings.[133]

Figure 16: Bondi Beach during the October 2015 heatwaves. Such large numbers seeking respite from the heat created significant traffic issues and placed extra demand on local emergency services. Source: Getty Images

Medical, public and mental health

- A clear association between extreme environmental heat and mortality has been established through analysis of extreme heat events, and the relationship between heat and health over longer periods of time.[134] Heatwave related fatalities usually occur on the same day of exposure, or within one to four days after.[135]
- The health impacts of heatwaves may be both direct and indirect. The direct effects are readily attributable to the heatwave and include heat-related illness such as dehydration and heat stroke as well as their sequelae (consequent condition) such as organ failure and potential cardiac arrest. However, it is the indirect effects of heatwave that cause the majority of excess mortality and morbidity during heatwaves and are far more difficult to identify leading to heatwaves being labelled a 'silent killer'.[136]
- These indirect effects lead to increased mortality rates among older populations and medically dependent persons with pre-existing conditions. Heatwaves are associated with increases in hospital admissions from kidney disease, deaths from cardio-vascular illness and deaths related to diabetes in elderly people.[137]

Coping with heat

- The human body needs to maintain a temperature of approximately 37°C to maintain normal body functions. Heatwaves can increase body temperature through radiation and conduction when the ambient temperature is greater than skin temperature. Heat loss can occur through convection and evaporation, through sweating, and assisted by behavioural changes such as seeking shade or other cooler locations. This is described in Figure 17 below.

Vulnerable groups

- The susceptibility to the effects of high ambient temperatures during heatwaves can be increased by factors affecting behaviour that cause additional increases in heat gain, interfere with sweating, reduce plasma volume or decrease cardiac output.
- These are summarised by NCCARF as factors influencing exposure, sensitivity and adaptation (see Figure 18).
- Some people may have multiple factors contributing, such as the elderly with co-existing heart disease (decreased cardiac output, reduced plasma volume and ability to

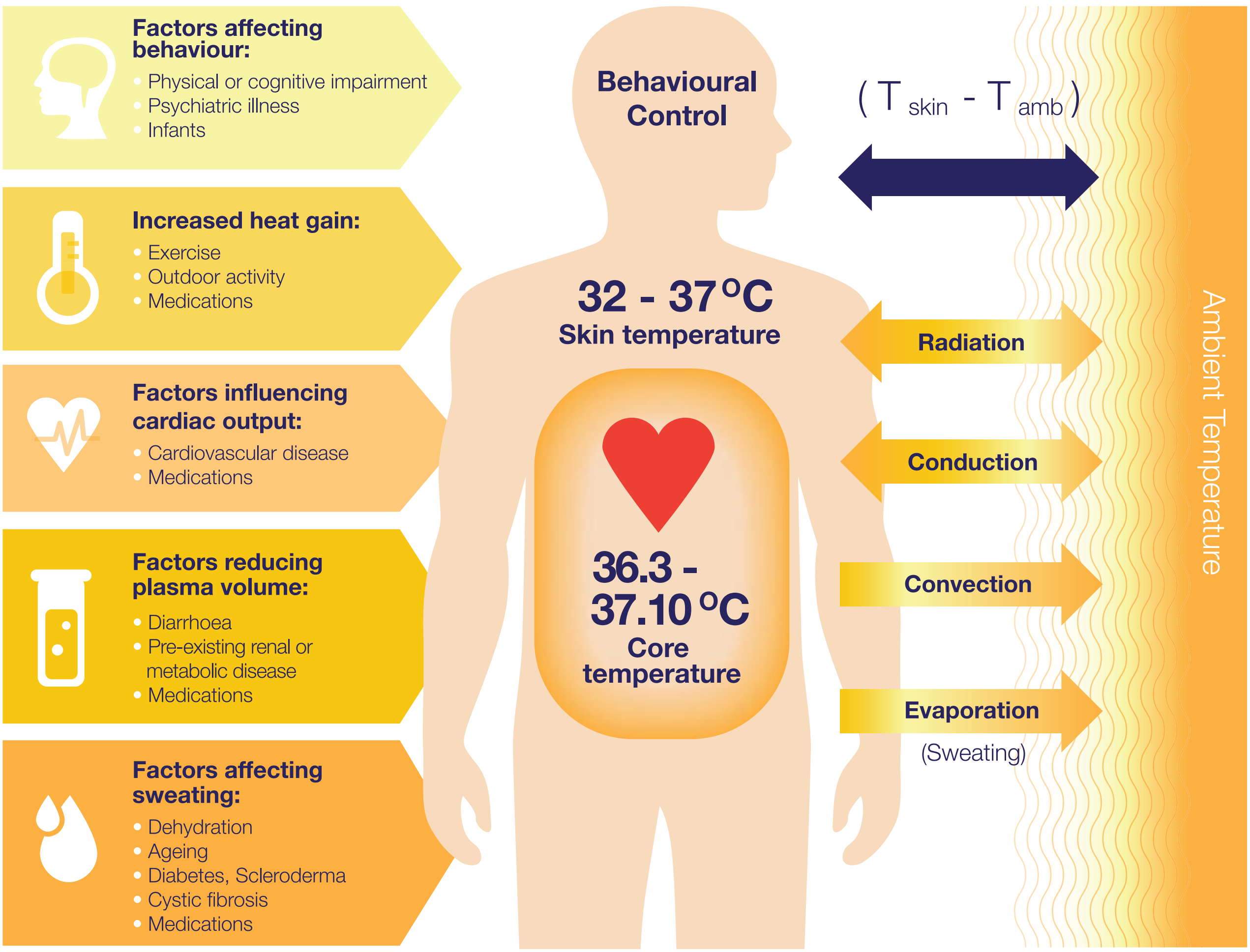


Figure 17: Human responses to high temperatures. Source: Queensland University of Technology

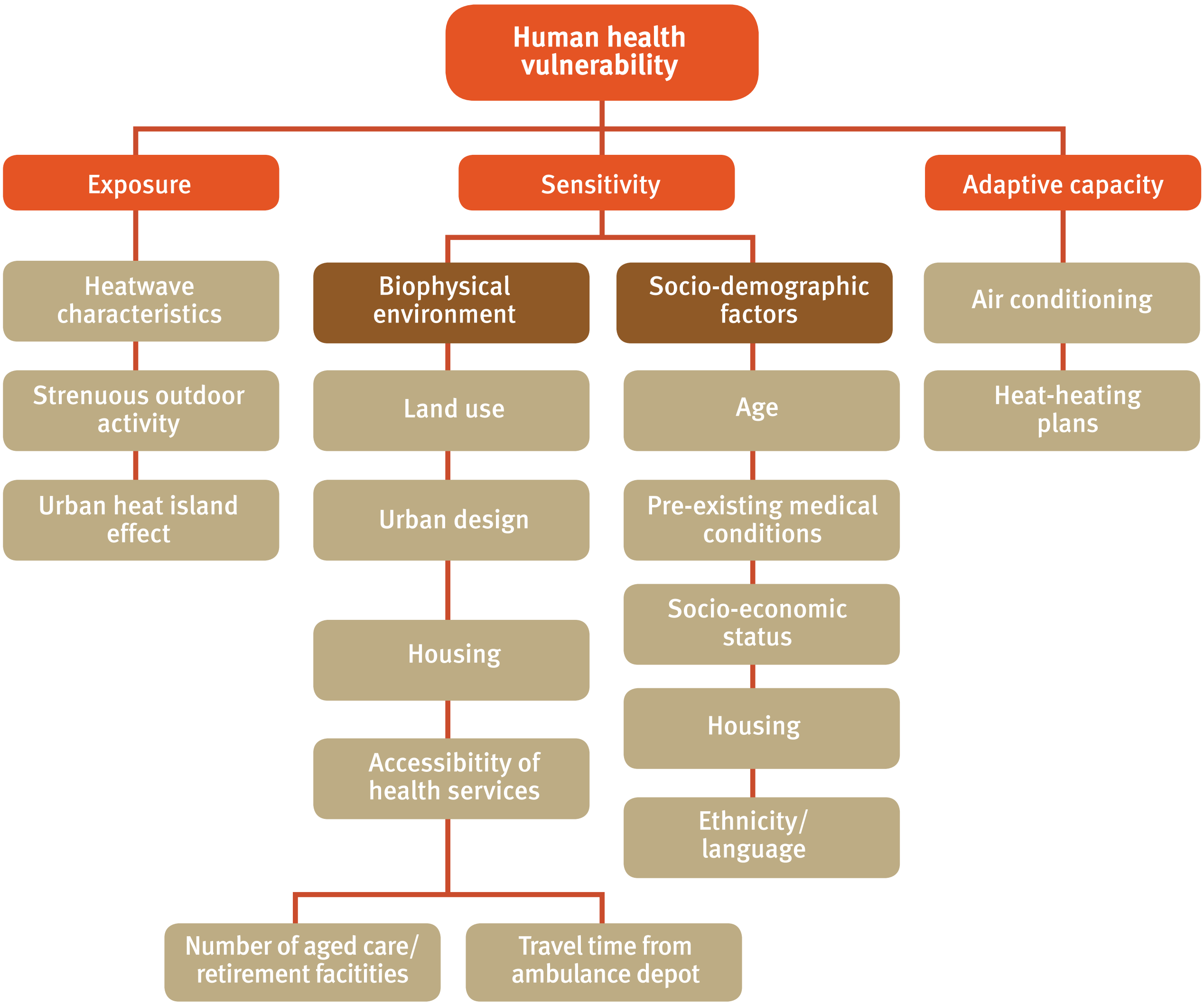


Figure 18: The multitude of factors that create vulnerability to extreme heat events. Source: NCCARF

sweat due to medications), who are also reluctant to use air conditioning because of costs.

- Those people especially at risk include the elderly, the very young, Aboriginal and Torres Strait Islander communities, people who work outdoors and those with compromised physical and mental wellbeing.[138]

Exposure

- Vulnerable groups living in cities are particularly at risk due to the urban heat island effect, which occurs because of a decreased amount of vegetation and increased areas of dark surfaces in urban environments, in addition to the heat produced from vehicles and generators. This effect is generally more prominent during the night than the day. This increases the likelihood of extreme high minimum temperatures for a more prolonged time and affects people's health by causing heat stress and, under very severe conditions, death from the cumulative heatwave effects.[139]

- Working or being active in hot and/or humid environments can be uncomfortable, and more importantly, lead to heat-related illness which can be fatal.[140] Heat-related illness may be contributed to by several factors either in isolation or together:
  - wearing high levels of personal protective equipment (e.g. Hazmat suits)
  - heat from extremely hot or molten material (e.g. foundries, steel mills, bakeries, smelters, glass factories and furnaces)
  - sun exposure (e.g. outdoor work such as construction, road repair, open-pit mining and agriculture)
  - high humidity (e.g. laundries, restaurant kitchens and canneries)
  - internal body heat (e.g. from heavy manual work)[141]
  - difficulty in accessing shade or places of respite from the heat during breaks
  - difficulty in accessing rehydration because of work location.

Sensitivity

- The way heat affects people varies from person to person and is influenced by:
  - general health, as a low level of fitness may make people more susceptible to feeling the extremes of heat
  - age (particularly for people about 45 years and older)
  - body weight (being overweight or obese can make it more difficult to cope with heat)
  - certain prescription and illicit drug use which can reduce the ability to sweat, reduce plasma volume, change behaviours or directly increase temperature
  - medical conditions – such as heart disease, high blood pressure, pregnancy, respiratory disease and diabetes, and some types of skin diseases and rashes – can also increase a person's susceptibility and may require special precautions
  - other factors include circulatory system capacity, sweat production and the ability to regulate electrolyte balance, all of which can be influenced by both acute and chronic medical conditions and medications[142]
  - their level of heat acclimatisation which generally takes approximately two to three weeks.
- The way in which people respond to heat is also influenced by their environment including preventive factors such as urban design, socio economic factors that influence housing design, cost of air conditioning, and employment; as well as health system access.
- Factors that reduce the effectiveness of heatwave warnings, such as language barriers, may place some individuals at risk.

Adaptive capacity

- Access to air conditioning is a major part of planning for most people and communities. This may occur through individual behaviours such as people going to shopping centres or through community arrangements where places of 'heat refuge', such as air conditioned libraries, are established for people to use during heatwaves. This allows the individual's body temperature to return to normal during heatwave conditions.
- Power failure (and subsequent lack of air conditioning) is often linked to increased heatwave morbidity and mortality.
- Loss of power during heatwave can also cause significant and rapid increases in temperatures within many buildings, as the design standards rarely make provisions for passive cooling or ventilation. For example, windows are not able to be opened, which creates serious concerns for providing relief from heat during long term power disruptions.
- Back-up power may also not be reliable during heatwave events due to a range of factors including precursor events or system faults. This may affect office blocks, hotels, hotels, schools, prisons, hospitals, and aged facilities.

Direct clinical effects of a heatwave: heat illness

Common clinical effects of a heat illness include:

- Heat rash, also known as prickly heat, consists of small, red, itchy or prickly skin lesions due to the plugging of sweat glands.
- Heat cramps are painful, often severe, involuntary spasms of the large muscle groups used in strenuous exercise. They tend to occur after intense exertion and often develop during heavy exercise while sweating profusely and replenishing fluid loss with non-electrolyte containing water.
- Heat exhaustion is considered a precursor of heat stroke. It may resemble heat stroke, with the difference being that neurologic function remains intact. Heat exhaustion is marked by excessive dehydration and electrolyte depletion, with symptoms including headache, nausea, and vomiting, dizziness, tachycardia, malaise and myalgia.
- Heatstroke is heat illness leading to a change in mental status, which may include an altered level of consciousness or seizures. The presence, or absence, of sweating is a poor guide to diagnosing heatstroke.
- Specifically, sweating does not exclude hyperthermia. Indeed, not all people who present with hyperthermia during a heatwave have heat illness. The most common causes of hyperthermia remain fever due to infection, or associated with other systemic diseases, malignancy or drug reactions

Clinical management of heat illness

- Rehydration and cooling are the cornerstones of clinical management of heat exposure.
- Most people can be managed in their immediate environment but immediate referral to medical care should be considered for anybody who fails to improve with fluids and cooling, has a change in mental status or has obvious significant consequent effects such as seizures, cardiac arrhythmia or cardia arrest.
- People experiencing heat-related symptoms must be moved to a cool environment as soon as possible or their surrounding environment cooled. Heat loss should be encouraged and supported with urgent cooling without causing shivering, which may increase core body temperature.

Public health impacts of a heatwave

- Hot weather also increases the risk of food-borne disease due to stresses in food production, particularly for chicken and eggs. Salmonella outbreaks are more common in hot months. These risks can be mitigated through more careful food handling practices.
- Loss of power also results in a loss of refrigeration of food, increasing risk of food-borne illness if not effectively managed.
- Loss of refrigeration can also cause damage to certain medicines, such as insulin and vaccines, reducing their efficacy.
- Loss of power can also result in the shutdown of water treatment plants and, depending on the availability of reserves in the system, may require the issuing of boil water notices. These risks will be managed by drinking water providers.
- Sewerage pumps may also cease to operate, leading to sewage overflows into the environment which may require advice to the community to avoid at risk areas.
- Longer term heatwaves also have the potential for a change in distribution and increase in vector borne diseases, such as Dengue and Ross River fever.

Mental health effects of a heatwave

- Mental, behavioural and cognitive disorders have been shown to be triggered or exacerbated during heatwaves, predisposing individuals to heat-related morbidity and mortality.[143]
- There is a positive association between high ambient temperature and increased hospital admissions for mental and behaviour disorders during heatwaves. Specific illnesses that have shown increased hospital admissions during heatwaves include symptomatic mental disorders, dementia, mood (affective) disorders, neurotic, stress-related and somatoform (manifesting as physical symptoms) disorders, and disorders of psychological development.[144]
- Fluctuations in weather have been noted to cause an increase in the incidence of mental stress, depression and suicide. As temperatures rise to extreme, the stresses of everyday home, social or work life are likely to be compounded by lethargy, lack of sleep and the inability to function normally during oppressively hot conditions.[145]
- Many medications used in psychiatry increase vulnerability to heat-related morbidity by altering the body's ability to thermoregulate. Drugs, such as antipsychotics, anticholinergics, antidepressants, sedatives and mood stabilisers that impair sweating and/or increase heat production, are used in the treatment of such conditions as dementia, Alzheimer's disease, psychosis, mood disorders, personality disorders and anxiety disorders.[146]
- Cognitive awareness of environmental conditions and the ability to undertake adaptive behaviours, such as increased fluid intake or wearing appropriate clothing, are important coping mechanisms that may be compromised in those with disabling mental illnesses such as Alzheimer's disease, dementia, senility, psychosis, schizophrenia and developmental disabilities.[147]
- Over the longer term, the effects of sustained heat and humidity, accompanied by drought, water restrictions, bushfires and power outages, are likely to have marked effects on the mental health of both rural and urban communities, with possible increases in the incidence of episodic or chronic stress, despair and depression, and health-damaging personal behaviours.[148]
- There is also a perception of 'inherent resilience' within regional Queensland communities, often depicted as 'stoic' and 'well-adapted' to the impacts of heatwave. While many of these communities have good levels of resilience to heatwave, this depiction can hinder the development of effective adaptation strategies.

Significant industries

- The wellbeing and productivity of workers is of concern across all industries. Heatwaves restrict work capacity and decrease the productivity of exposed workers.[149] People who work outdoors or in enclosed indoor spaces without adequate ventilation, even if young, fit and healthy, are highly vulnerable during extreme heat events. This vulnerability extends to a broad range of people including labourers, military personnel, athletes, farmers, emergency and essential service workers, and those working outside in the mining industry.[150]
- In addition to heat illnesses, extreme heat can also lead to mental health problems in workers, such as aggression, confusion, psychological distress and other behavioural changes.[151]
- Studies have shown that lost productivity through impacts on heat-affected workers cost Australia more than $8.8 billion dollars annually. This figure is expected to rise due to climate change and in the absence of strong mitigation measures.[152]
- As the frequency and intensity of heatwaves increases due to climate change, increased hospitalisations and considerable associated costs due to lost productivity can be expected.[153]

Transport and logistics

- Movement of heavy machinery and transport on 'bleeding' pavements may cause surface damage.[154]
- Effects of heatwave on the road and rail networks may impact transport and logistics operations, especially where:
  - track buckling has occurred
  - load limits have been placed on the road network
  - damage to pavement has occurred.[155]

Agriculture, fishing and forestry

- Severe and extreme heatwaves can have significant impacts on agricultural crops and livestock. Sustained elevated temperatures over several days can substantially reduce crop yield and quality, and affect the productivity, health and wellbeing of stock.[156]
- Livestock will be exposed to a greater risk of heat stress. They are unlikely to travel as far to water which concentrates grazing pressure and increases the risk of adverse pasture composition changes and soil degradation.[157]
- Higher temperatures may increase activity of soil-borne diseases and insect infestation, for longer periods during the year.[158]
- Heatwave intensification is anticipated to impact on the forestry industry's resources through increased fire risk, personnel (heat stress and fire response), and plant and equipment (due to overheating).[159]
- Fire risk in forested areas will be accentuated by forecasted increases in drought conditions and decreases in precipitation and humidity. Fire impacts could have immediate implications for resource supply. Growth impacts may affect long-term supply of forestry products.[160]
- Water and irrigation requirements may be increased with higher temperatures.[161]
- An increase in bushfire risk during heatwaves may result in death of livestock, crop loss and damage to agricultural assets and equipment.[162]
- Increased temperatures in freshwater fisheries can result in earlier spawning, skewed sex ratios and decreases in oxygen levels.[163]
- An increase of coral bleaching events will potentially impact commercial fisheries within the Great Barrier Reef.[164]

Tourism[165]

- Heatwaves are often overlooked as a significant weather risk to the tourism sector. Yet they can have a significant impact on ecosystems by reducing biodiversity (e.g. Great Barrier Reef and other fragile ecosystems) and, in turn, visitation to Queensland for eco-tourism may be negatively affected.
- Increases in temperatures are a risk to impacts on terrestrial biodiversity that may change or reduce key tourism destination experiences, attractiveness, and participation.
- Heatwaves pose a significant risk to tourists – particularly international tourists, tourism infrastructure and natural assets – and could also negatively affect perceptions of safety, increasing the reputational risk for the tourism industry.
- Enjoyment of Queensland attractions and experiences may be impeded when an extended period of extreme heat impacts outdoor activities or prevents tourists from leaving their accommodation.
- Use of Queensland's hiking trails and many eco-tourism experiences may decline as the capacity for strenuous physical activity drops off rapidly as heat loading increases above a coping threshold.
- Factors directly or indirectly exacerbated by persistent heat, including air conditioning and refrigeration costs for industry and food storage, have the potential to increase costs in tourism business, which in turn affects Queensland's ability to offer a value for money tourist experience.
- A Melbourne study found that local businesses lost 10 per cent of revenue in the January 2014 heatwave. The study further established that 59 per cent of businesses in the city experienced additional operational costs (e.g. for air conditioning or cancellations) as a result of hot temperatures. Hospitality, retail and tourism industries were most affected.[166]
- There is a danger that more extreme weather events will make it difficult for organisers to attract and host major tourism initiatives, particularly sports-related events. In South Australia in 2018, organisers of the Santos Tour Down Under – an international cycling race – were forced cancel major flagpole public participation events because of the heat. This in turn has affected the organiser's ability to obtain insurance for the event; indeed, it is becoming increasingly difficult to insure against extreme weather events.
- Heatwaves are also expected to cause localised blackouts in some parts of the country due to increased demand on electricity generation, which in turn may impact on a visitor experience to Queensland.

Environment

Marine ecology

- Marine heatwaves are defined as temperatures warmer than 90 per cent of the previous sea surface temperature (SST) observations at the same time of year over a 30-year period, for at least five days in a row.
- Marine heatwaves occur when sunlight passes through the atmosphere and heats the surface of the ocean. When there are weak winds, this warm water does not mix with the cooler waters below; it sits on top and continues to heat. Such warming can be local (such as when a high-pressure system remains slow moving for an unusual period) or large scale, covering much of an ocean basin, as can occur during El Niño/La Niña events.
- Marine heatwaves can result in mass bleaching of the Great Barrier Reef (see Figure 19 below). Branching corals are most vulnerable and bleaching events can significantly impact ecology and biodiversity of the reef as these corals provide habitat for fish and other sea creatures.[167]

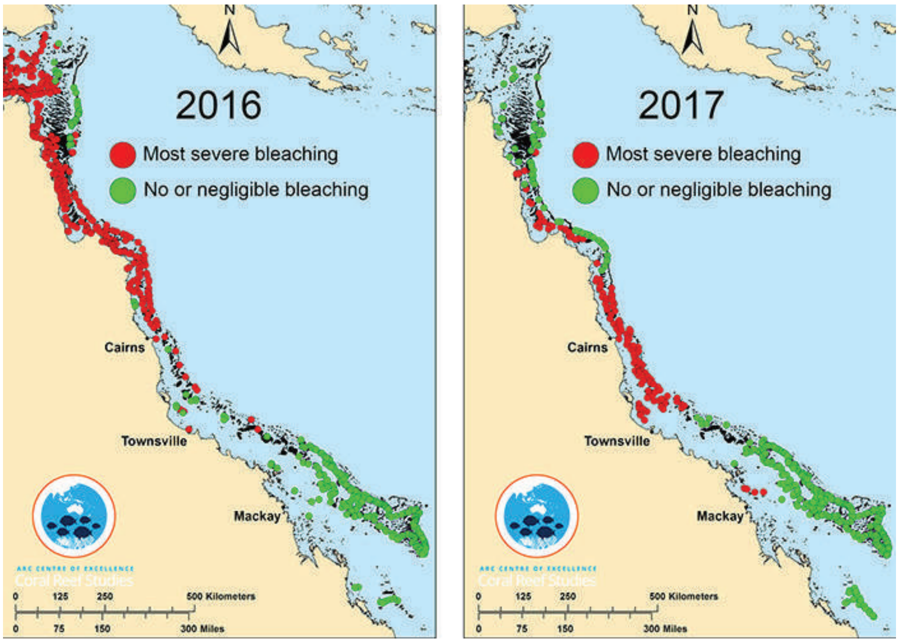


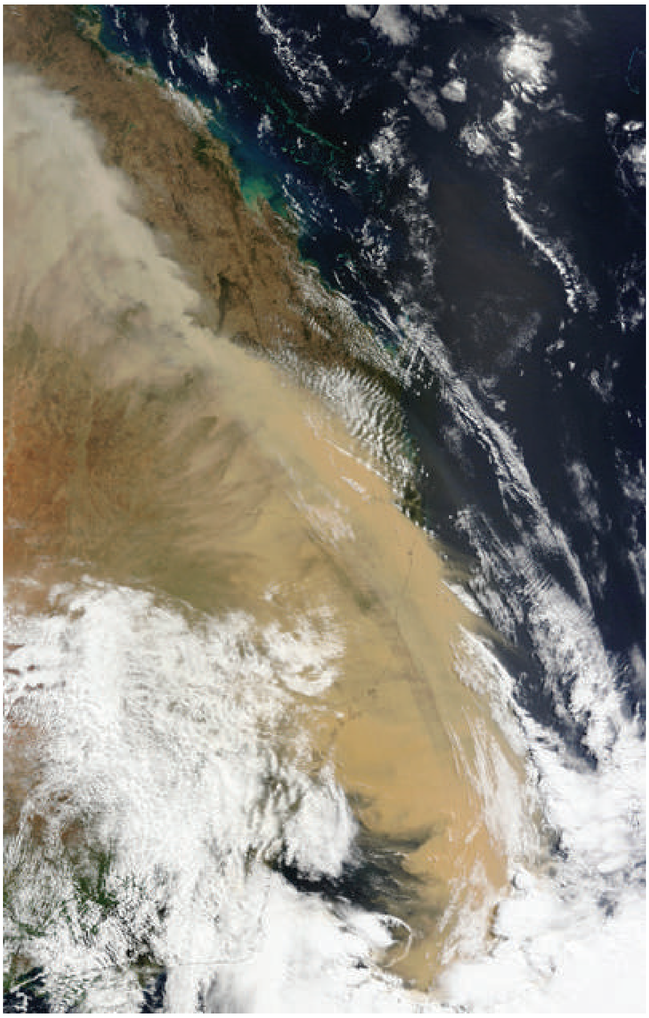
Figure 19: Main areas of coral bleaching in 2016 and 2017. Source: ARC Centre for Excellence for Coral Reef Studies

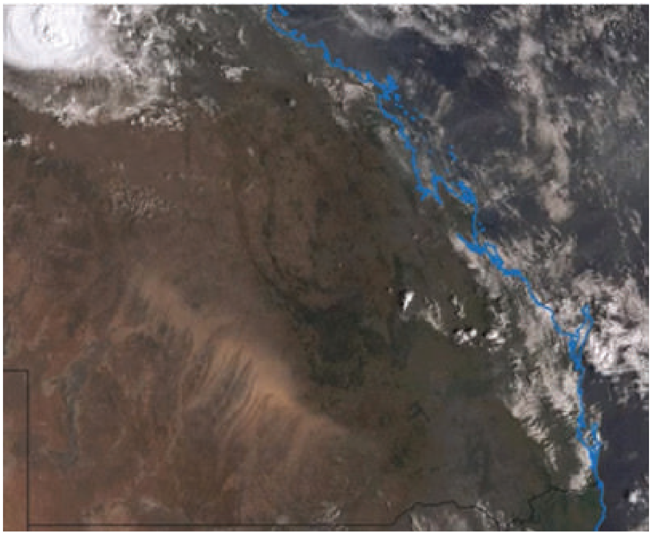
Riparian ecology

- Heatwaves and higher temperatures increase the risk of extinction for endangered species such as the Mary River cod and freshwater spiny crayfish.[168]
- Higher temperatures can bring increased occurrence of algal blooms and more instances of fish kill incidents in freshwater ecosystems.[169]

Terrestrial ecology

- Heatwaves can trigger mass deaths of heat-sensitive species such as flying foxes and birds.[170] Plants can also die following extreme heat events, with some species more vulnerable than others.[171]
- Mass deaths of species such as flying foxes can result in ecosystem impacts on areas such as the Wet Tropics of Queensland World Heritage Site due to the significant role of these species in seed dispersal and pollination. Recent studies have shown that mass-death events of such species may prevent the propagation of millions of trees within the wet tropics.[172]
- Long-term consequences of heatwave include changes in species assemblages, extinction of the most vulnerable species and increased forest fuel levels – with the latter being a risk factor in bushfires.[173]
- Exacerbation of desertification, the process of places becoming more dusty, dry and desert-like over time, is likely to occur under the influence of climate change through a repeated cycle of heatwaves, drought, bushfires and dust storms. Notably, the 2018 Queensland bushfires coincided with a series of severe and extreme heatwaves, and large-scale dust storms that swept across Queensland, which bring with them their own inherent risks to human health and public safety as illustrated in the photos below.[174]





Satellite images of the 2009 (left) and 2018 (right) dust storms which impacted vast areas of the State. The associated image (top right) is of the impact to Brisbane on 23 September 2009. This dust storm led to poor visibility and hazardous air quality with increased risk to those with heart and respiratory conditions.
Source: Queensland Fire and Emergency Services

RISK ANALYSIS

Risk analysis

This section details the consequences of the impact against the five key components of the community:

1. People – injuries sustained and numbers of casualties
2. Financial and economic – impacts to infrastructure, cost of recovery and impacts to the local, regional or State economy
3. Community and social – impacts to the community, the infrastructure on which it depends and the connectedness of those communities
4. Public administration – impacts to and criticism of response
5. Environment – loss of ecosystems and assets of significant environmental value.

The level of consequence is determined through an assessment of the severity of exposure, the level of vulnerability, the coping capabilities and capacities of the communities involved, and the potential consequences under both the current and future climate.

People

Likely consequence: Major to Catastrophic

- Increased mortality rates to be expected among aged populations and those medically dependent persons with pre-existing conditions (e.g. people on life support, people with heart disease or renal failure). Aboriginal and Torres Strait Islander communities are highly vulnerable during heatwaves due to a generally lower state of health compared to the wider community.
- Individual heatwave events, such as those experienced in 2004 in Brisbane and 2009 across South Australia and Victoria, have resulted in the attributable deaths of hundreds of people.[175]
- Challenges in identifying heat-related incidents as the causal factor for presentation to emergency departments or calls for assistance is still a barrier to understanding the true impact of heatwaves on people (as previously discussed within on page 25 & 34).
- Accordingly, the identified consequence rating – Major to Catastrophic – should be used until uniform, accurate and actual heatwave impacts on human health can be identified and interrogated. Otherwise, it is likely that the true impacts of heatwave on populations (based on statistical analysis of unrepresentative morbidity and mortality rates) will remain mostly hidden.

Financial & economic

Likely consequence: Moderate to Major

- In other Australian states, impacts from individual severe and extreme heatwaves that persist over a broad area have resulted in major state-wide power outages, significant stresses and strains on services organisations, and a loss of general productivity.[176] Within Queensland, it is likely that these impacts will be localised or felt regionally, given the State's size and population spread. State-wide impacts may arise when heatwaves correspond to the occurrence of another hazard such as bushfires or a cyclone.
- In areas where the impact and disruption from a severe to extreme heatwave is more localised, it is expected that economic losses will be less severe (moderate) and confined to the short to medium term.
- Where the heatwave leads to extended periods of disruption and greater impacts to infrastructure, recovery costs for damage to infrastructure and non-supply periods are likely to be high.
- Under the current and projected future climate, an increase in heatwave events and associated health impacts is expected to result in increased costs for both government funded and privately funded health services.
- The projected increase in heatwave events is likely to lead to longer periods and a greater extent (geographic) of economic loss due to the disruption caused by increasing frequency and intensity of events.
- The growing need for infrastructure and community resilience programs, that seek to adapt to the current projected future climate, will put increasing pressure on operational budgets, particularly where this has not been accounted for in forward estimates, and where mitigation funding streams are limited.
- Increase in livestock, fish stock, and crop losses as a result of the exacerbation of drought conditions may result in significant consequences for already strained business owners and communities.

Community and social

Likely consequence: Moderate to Major

- Increased pressure on human resource response for community and social services should be expected, as well as for areas and events that may increase vulnerability, such as sporting events, concerts and beaches.
- Increased demand for community, social and welfare services by those highly susceptible to the effects of prolonged heatwave conditions will become more acute within areas that are experiencing an increase in the aged population over the long term.
- More frequent and prolonged heatwave events may continue to impact on the community's collective mental health. There is a demonstrable link between prolonged heatwave events and a reduction in short-term community cohesion.

Public administration

Likely consequence: Moderate

- Increased demand on emergency services, frontline services and community and social services, with requirements for extended hours of operation and some impact to normal servicing provisions is expected. This is likely to cause delays in service during the period of immediate effect of heatwave events and add to financial impacts beyond normal budgeted operations for responding agencies.

- Increased demand on health services is anticipated during heatwaves, especially from vulnerable groups such as older people, young children, people with chronic disease and those living in high density urban areas.
- Perceived lack of preparation for non-traditional hazards (such as severe and extreme heatwaves) can lead to sharp criticism of governing bodies, organisations and business owners. This is especially true in the occurrence of attributable injuries or deaths. For example, heat-related mass mortality of wildlife from recent events has drawn sharp criticism of local governments.
- Lack of perceived action on the issue of climate change is a growing source of concern within the communities of Queensland.[177] There is an increasing likelihood of legal action against governing bodies, financial organisations and businesses from motivated sections of the community.

Environmental

Likely consequence: Catastrophic

- Large scale bush and wildfires across areas of national parks, State forests and Areas of Ecological Significance have been observed as a result of exacerbated bushfire conditions.
- Mass deaths of vulnerable species such as birds and flying foxes can be expected, which may also contribute to water, sanitation and hygiene-related contamination.
- Increased likelihood of repeated mass bleaching events on the Great Barrier Reef due to greater propensity for marine heatwaves. Loss of associated marine species and the impacts to dependent businesses (tourism) will increase.

Risk statement

The purpose of the risk statement is to provide a concise summary of the risks and potential consequences associated with the occurrence of the hazard. It is designed to form the basis of a briefing note and/or community messaging and can be adapted for use by any emergency management practitioner or stakeholder.

The manifestation of a heatwave event may lead to multiple and simultaneous impacts across broad areas of the State resulting in increased vulnerability for various sectors of community.

During severe to extreme heatwave events, there is a high likelihood of infrastructure damage and potential failure due to the effect of sustained high temperatures and the risk of increased bushfire intensity. These impacts have the potential to lead to localised to widespread outages across the power network, especially in periods of peak demand. The water supply network has an increased risk of disruption to services as sustained high temperatures increases the likelihood of water mains failure. There is also an increased risk of contamination through bacterial growth within water storage which may present additional public health concerns.

Extreme heatwave events can lead to critical injuries and fatalities through exposure to the underlying heatwave conditions. Human coping mechanisms will come under significant stress and many within the community may require assistance during these events through a coordinated response and the provision of mechanical and natural cooling. Higher levels of impact may occur in those with pre-existing renal, respiratory and/or heart conditions, and in elderly populations (65+), all of whom have been identified as being increasingly vulnerable during severe and extreme heatwaves. Those with limited access to air conditioning or who lack redundancy in supply of power and water are at increased risk of exposure to heatwaves.

Local and State government services (such as schools, facilities management and maintenance services) may be suspended where local temperature thresholds are exceeded. This is especially likely in services that are delivered outdoors.

Short-term disruption to major road and rail systems due to infrastructure damage may lead to localised and regional economic impacts. There is potential for a significant increase in the movement of people seeking respite out of urban and into coastal areas and other 'cool places of refuge'. This may significantly increase road traffic crash risk as the volume of vehicles moving towards these areas grows.

The onset of a prolonged or acute heatwave event is likely to correspond to an increase in calls for service to emergency services as the risks to human health and other societal risks increase. Heatwaves can increase underlying bushfire risk to potentially extreme levels. Any resultant bushfire occurrence would add significant pressure to the local and regional emergency management capability and increase the risk of impact to the general community.

Substantial impacts to the agricultural community and wider sector are almost certain due to the impact of sustained elevated temperatures on crops, livestock, and the exacerbation of pre-existing drought conditions and underlying bushfire risk.

The Great Barrier Reef, national parks, conservation areas and wildlife populations are extremely vulnerable to heatwaves and additionally to the associated risk of bushfires.

Potentially significant recovery costs from damage to infrastructure, business interruption and bushfire impact is possible. This may lead to instances of economic assistance being requested from local or State bodies and funding mechanisms.

Heatwaves can potentially occur prior to or after the impact of another major disaster such as a bushfire or cyclone. The occurrence of a severe or extreme heatwave in conjunction with these other natural hazards may further compound the outlined risks.

RISK TREATMENTS AND CONTROLS

Risk treatments and controls

General overview

Adaptation strategies for extreme heat events must include elements of pre-season planning and preparation, education, early warning systems, and targeting of prevention and response strategies to vulnerable groups. Response strategies must address the characteristics and locations of vulnerable groups to efficiently and effectively allocate resources.[178]

Additional sector specific long-term risk management considerations can be found within the individual 'Sector Adaptation Plans' which form part of the Queensland Climate Adaptation Strategy (Q-CAS).[179]

Commentary: A coordinated approach - The New South Wales Government State Heatwave Subplan

The aim of the New South Wales State Heatwave Subplan is to detail the multi-agency arrangements for the control and coordination of, the preparation for, response to, and immediate recovery from, heatwave events within New South Wales (NSW) to reduce the risk or counter the effects on people, property and the environment.

In 2011, the NSW State Emergency Management Committee endorsed the subplan as the mechanism to oblige all NSW state government agencies and local governments to address heatwave events in their emergency management planning.

The subplan denotes that all regions and local governments should consider heatwave events as having at least a 'High Risk' in their planning considerations and where necessary, develop appropriate regional and/or local arrangements to manage any functions required in the warning of and during extreme heat events (including heatwaves).

Each state agency mentioned within the subplan is required to develop an internal Concept of Operations or procedures to detail how its respective roles and responsibilities under the subplan will be fulfilled.

The subplan may be activated for the whole or part of the State in relation to an area affected by the extreme heat or heatwave event.

Prevention and mitigation

Essential infrastructure

- Energy Queensland's Demand Management Programs seek to reduce network demand by providing incentives to households to connect hot water systems, pool pumps, and air conditioners to load control programs which allow the network operator to remotely reduce the consumption of the connected electrical equipment.[180]
- Effective planning and investment in adaptation requires a good understanding of at-risk areas. Programs that map 'hot spots' or urban heat islands should be used to underpin targeted investment that reduces extreme heat risks.
- Adapt existing infrastructure and plan any new infrastructure to take into account extreme heatwaves and long-term projection of future climatic impacts.
- Telstra core communication infrastructure has been engineered with layers of redundancy, both within Queensland and in other states. Strategic infrastructure sites are supported by multiple diverse internal power systems, multiple backup generators and air conditioning redundancy.
- Non-strategic communication sites through to roadside cabinets have been designed to suit local environmental conditions and/or will also have varying degrees of air conditioning installed. Heat-related network component failures are managed and prioritised through business as usual restoration processes.
- Telstra dictates its own power restoration priority to ensure its critical infrastructure is maintained. Emergency services, local council and Queensland Government requests will be incorporated in the restoration priority request process where they do not directly conflict with Telstra's core network infrastructure priorities. Depending on the length and severity of an event, additional resources can be accessed from outside the area or interstate to ensure the resting of resources while sustaining long-term support.[181]

Access and resupply

- Public transport regulations in Queensland require bus operators to ensure fitted air conditioners are fully operational, and air conditioners are turned on when the area forecast is above 28°C. When air conditioning is not fully operational, bus operators are required to advise passengers on entry.[182]
- Replacement of timber sleepers with concrete sleepers can increase resilience of the rail network to heatwaves by helping to prevent track buckling.[183]
- Designated parking, around public and community infrastructure, in shaded areas for the elderly and people with a disability.[184]
- Good pathway connectivity in high density urban environments can promote active transport and help with acclimatisation,[185] however shade and shaded seating in public areas, as well as drinking fountains, should be incorporated into active transport networks.[186]
- The following urban spaces should be prioritised for protection against heat:
  - bus stops/shelters
  - public exercise areas
  - west facing pedestrian areas around schools
  - main intersections
  - car parks
  - footpaths, verges, roads, roundabouts (road reserves).[187]

Community and social

- Encourage behavioural adaptation strategies within the community to reduce reliance on mechanical cooling and ventilation. These strategies are outlined in: Case study - Putting people first - managing the human health impacts of heatwave on page 57.
- Incorporate the QDesign principles[188] within building design and urban planning to improve mitigation of heatwave impacts and general wellbeing (Refer Appendix D: Building design, urban design and urban planning – a guide for Local Government on page 79).
- Install solar panels to offset the cost of air conditioning, especially in public buildings where primary use often occurs during the daylight hours. These buildings can also be used as places of cooler refuge during heatwave conditions.
- The cost of electricity can often be a barrier to air conditioning installation and use. The Advancing Clean Energy Schools (ACES) Program, implemented in 2017 by Queensland's Department of Education, provides $97 million over three years to reduce energy costs to State schools through solar and efficiency measures. Testing is also in progress to provide solar for public housing to help reduce operating costs.[189]
- Planned maintenance schedules across State education infrastructure is yielding an increase in the availability of air conditioning in schools and houses for teachers in remote areas.[190] Further, the ACES Program is investigating opportunities to increase and improve the use of solar generation in this space to increase overall redundancy of supply, efficiency and sustainability (by converting small solar PV systems to larger PV systems).[191]
- Traditional adaptation to the climate by Aboriginal people in hot regions of Queensland included building shelters appropriate to the season. Documented evidence of shelters built by Aboriginal people shows that they adapted to the climate by building and living in a variety of shelters suited to different seasons.[192] It is therefore important to keep the construction industry and wider community informed of the heat risks associated with building design, and the importance of passive design features that can be adapted to different seasonal requirements. This may influence adoption of building design features more suited to mitigating heatwaves.
- Deliver community messaging and awareness campaigns through trusted stakeholders such as Local Disaster Management Groups (LDMGs), general practitioners and medical centres, community groups, communities of learning (CoL), and senior members of religious organisations to drive awareness and response. This can also assist in the preparedness phase.

- Those who work with the members of communities who are more likely to be vulnerable to extreme heat (e.g. socially disadvantaged, disabled, elderly, very young, those from a non-English speaking background) are best placed to help them adapt.
- Provision of accessible, appropriate and free cool public spaces are important for the wellbeing of many vulnerable people within the community.[193] Well-lit public spaces will encourage people to cool down safely in the evenings and can promote social cohesion and networks, reducing the risks associated with social isolation.[194]
- Conducting hazard reduction burns during cooler periods will reduce the risk of bushfire occurrence and intensity.

Governance

- Increasing the understanding among executives and board members in relation to their fiduciary responsibility and potential for personal liability if they fail to account for heatwave related climate risks in strategic and operational plans can help to address risk and legal liability issues.[195]
- Governance arrangements to address the impacts of extreme heat need to consider not just the response to heatwaves but also a broader perspective on planning and preparedness for extreme heat in the future. Planning timeframes differ for each sector and stakeholder and, accordingly, these should be identified, mapped and integrated into a clear planning horizon. Typical planning horizons are shown in Figure 20 below.
- The responsibility for developing proactive strategies for reducing the impacts of extreme heat as well as responding to community need during extreme heatwaves falls across a broad range of sectors and organisations. The challenge of coordinating responses and ensuring the most appropriate governance arrangements are in place was highlighted in the extreme heatwave experienced in southern Australia in 2009.
- Building partnerships with and among stakeholders that have existing relationships with and channels into communities would support a unified and consistent response for mitigating the impact of extreme heat on communities. This might include local governments, local doctors (messaging), shopping centres (for refuge) and community organisations (checking on or transporting vulnerable people to shelter).
- Encouraging the development of partnerships between agencies and sectors, such as the Bureau of Meteorology's Heatwave Service, which provides direct information to health and care service providers, would also prove beneficial.

Significant industry

- Regionally focused adaptation strategies for primary industries are available in the 'Climate Impact and Adaptation Series' brochures.[196]
- Clear agreements with workers on how to manage extremely hot days or identify periods of time where weather and climate affect working conditions are highly beneficial.[197] As an example, the United Arab Emirates often experiences extreme heatwave conditions and enforces mandatory breaks for outdoor workers from 12.30pm to 3.00pm during the hottest months of the year.[198]
- Industries with the option to shift to night time schedules for the duration of heatwave events may be able to mitigate or prevent heat-related injury or illness by implementing this approach.
- Use crop protection treatments including solar radiation shading and evaporative cooling through overhead irrigation to maintain fruit quality.[199]

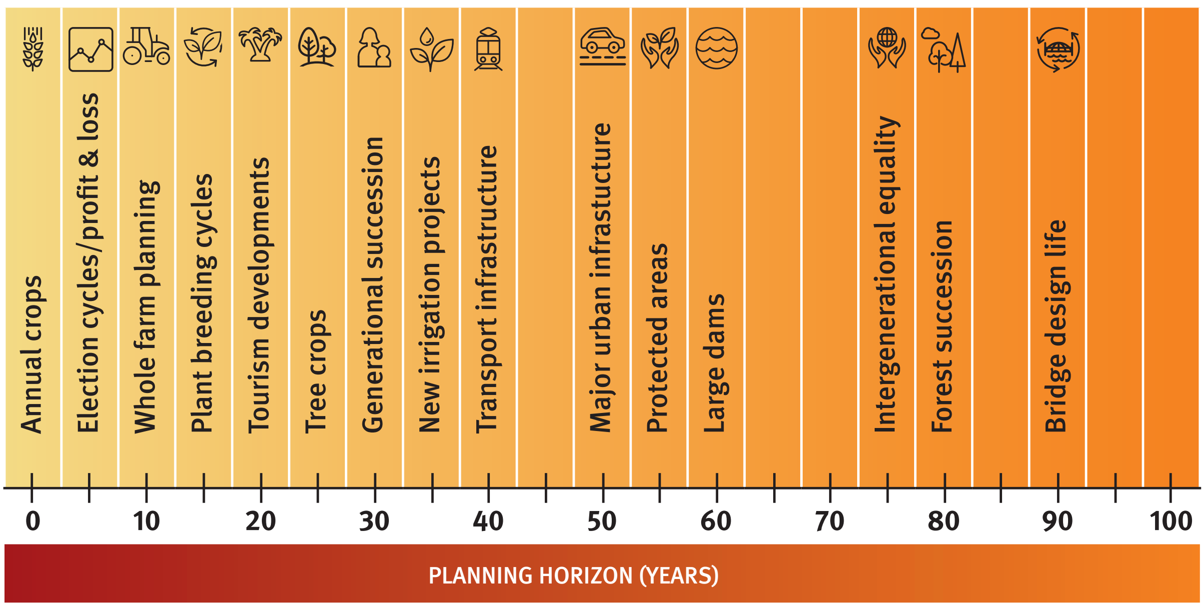


Figure 20: Typical planning horizons (years) for different sectors. This highlights the need for a coordinated approach when dealing with long-term climate change adaptation. Source: Climate Change in Australia

Environmental

- Green infrastructure (which can include trees, wetlands and shading) has been demonstrated to be an important tool in reducing heat, particularly in urban areas. Planning and investment in green infrastructure, which can be incorporated in current planning, will reduce the impact of future heat increases. To this end, the core mitigation response is clear: plant trees for shade in public open spaces.[200]
- Community and developers must be educated to ensure they understand the benefits and amenities provided by green infrastructure. Community awareness can lead to pressure on developers to incorporate elements of green infrastructure into their designs.
- Designs that target social connectedness may help foster greater community resilience, a key driver in reducing the risks for vulnerable members of the community. New incentives and regulations may be needed to facilitate the inclusion of green infrastructure in public places and shared spaces. An integrated planning approach would help in the consideration of other factors and stressors, such as ensuring there is availability of water to sustain green infrastructure.
- Increase environmental flow allocation and water aeration to improve freshwater ecosystems' resilience to heatwaves.

Preparedness

Essential infrastructure

- Some Australian industries with high heat vulnerabilities are embracing weather-risk management for heatwaves in terms of insurance options, such as weather derivatives and index-based insurance.[201]
- The Queensland Government-owned Energy Queensland (EQL) group undertakes detailed preparation and planning for the summer season in Queensland. In the lead up to the summer storm season each year, EQL develops a Summer Preparedness Plan in conjunction with significant preparation activities aligned to four major focus areas:
  - Pre-summer network preparations – preparing the network to ensure the capacity and security of supply will meet summer energy and peak demand
  - Network resilience – maintaining the network to minimise the impact of extreme weather events on customers' electricity supply
  - Emergency planning and response – planning for, identifying and responding to disruptions, natural disasters and emergencies that impact on customers' electricity supply
  - Communication – continuing to provide timely and accurate communication with Ergon Energy Network's and Energex's stakeholders, customers and the media, in relation to network disruptions.[202]

Access and resupply

- An active lifestyle and regular use of active transport (e.g. walking, cycling) can help people to maintain naturally high levels of heat acclimatisation.[203]
- Field technicians deployed during hot weather for monitoring at high risk locations on the rail network can identify issues and help to prevent potential derailments.[204]

Community and social

- Informing the community about ways to manage the personal impacts of heat and how best to look out for the wellbeing of vulnerable people can support adaptation to heatwave conditions. Queensland Health (QH) provides advice on preventative strategies and key messages.[205] To ensure the effective delivery of this information, it needs to be:
  - in plain and simple language
  - specific
  - regular
  - consistent
  - targeted
  - translated for culturally and linguistically diverse groups
  - available in a variety of formats
  - able to be remembered and acted on
  - achievable by the public.[206]
- Messages providing targeted advice, such as those from QH and Surf Life Saving Queensland, should be prepared to be readily disseminated as required.
- A broad range of media, including social and alternative channels used by particular groups (e.g. tourism and community-specific groups), should be used for these targeted messages and advice to ensure widespread coverage and comprehension.
- Information needs to be particularly tailored to vulnerable people, including tourists and new residents, and to focus on behaviour. An example of this is encouraging older people to use air conditioning (by highlighting real cost for short-term use), to turn it on early in the day, to introduce passive cooling measures in the home or to move to cool retreats early.
- A key element for the above strategies is to follow, support and promote QH advice as it is the primary agency for heatwave as well as lead for health services. Confusion among the community can occur when individual entities create messaging that is inconsistent with or contrary to QH advice.
- Government advice is available on how to reduce heat impacts in housing, government buildings and urban planning. The 'your home' website and guide at www.yourhome.gov.au is a key resource. However, this and other such advice only presents guidelines with limited mandatory requirements.
- Features for new buildings and methods of retrofitting existing structures may help to increase resilience of building stock and subsequently building occupants. This may include conducting a heat audit and mitigation program for the homes of vulnerable population groups and education on personal heat mitigation strategies.[207]

Medical

- Ensure communities and response agencies have appropriate arrangements in place to manage human health impacts.
- Maintain a clear understanding of heatwave risk, and how elements within the community may become more vulnerable during heatwave. For example, it may require rescheduling or cancellation of activities or events due to unacceptable levels of heat exposure.
- QH continues to provide community education and engagement strategies that include:
  - heatwave preparedness advice (e.g. self-management of heat stress, recognition of heat illness and food safety strategies) in summer preparedness campaigns
  - development and provision of targeted information for vulnerable groups and those who support, or care for, people at risk of serious health effects from heat
  - the provision of advice and information sheets for the public, Hospital and Health Services (HHSs) and other government and non-government agencies.
- Heatwave preparedness activities are integrated with summer season preparedness activities, which are common across all organisations involved in Queensland's disaster management arrangements. These activities include ongoing initiatives such as 'Get Ready Queensland'.
- Refer to the case study: Putting people first – managing the human health impacts of heatwave on page 59 for more advice on medical and health preparedness measures.

Significant industries

- Graziers can arrange water points to reduce distance to water for livestock and to better balance grazing pressure on their properties.[208]
- Consider breeding programs for heat tolerant, low chill and more adaptable varieties of various horticultural crops.[209]
- Incorporate greater use of prescribed burning to reduce the risk of wildfires and control woody thickening.[210]
- Incorporate climate risk management into ecosystem-based fishery management including further developments in bycatch reduction and improved targeting practices.[211]

Case study: Embracing safe work practices – Sunwater's procedures for working in hot environments

The need

Sunwater is undertaking a Spillway Improvement Project to assure the structural integrity of the Fairbairn Dam during significant flood events. Fairbairn Dam is situated on the Nogoa River in Central Queensland, approximately 16 kilometres south-west of Emerald.

The Fairbairn Dam supplies irrigation water to the Nogoa-Mackenzie irrigation area and municipal supply to the city of Emerald. Due to temperatures during construction being recorded regularly above 40°C between November and March, the need to manage the health and wellbeing of personnel while maintaining the delivery schedule was identified.

The solution

Workshops were undertaken to develop a procedure that identified the key safety requirements for effectively managing potential heat stress situations during tasks where extreme temperatures may be encountered.

These workshops comprised consultation between management and the workforce, reviews of codes of practice and industry guidelines, analysis of existing cases where personnel were required to work in hot environments and advice from external stakeholders.

The procedure's key purpose was to manage potential adverse health effects caused by exposure to heat by identifying and implementing suitable controls and enabling workers to manage their hydration and fatigue when working in such hot environments.

References and associated documentation used throughout this process included various internal policies and external documents including government guidance material, legislation and Australian Standards.

The outcome

The Sunwater WHS33 Managing Working in Hot Environments procedure was first trialed as a site-specific practice at the Fairbairn Dam Project and has since been adopted across the business. The roll out on site, delivered through toolbox talks and the induction process, has not required substantial change to the practical controls already implemented. Rather, the procedure provides clarification of everyone's role and responsibilities, and documents the key safety requirements for effectively managing potential heat stress situations during specific tasks where extreme temperatures may be encountered.

The content of this procedure has been positively received, with a particularly rewarding ancillary outcome being the camaraderie that has developed among the team.

A notable piece of feedback since the procedure's introduction came from a member of the concrete form-reo-pour crew, which was: "What's this all about? This what we do! It's nothing new."

This statement is true. The procedure is nothing new. However, having it agreed upon, shared and documented ensures clarity, consistency and, most importantly, safety.

Simplicity, practicality and the inclusion of end users in decision-making are key learnings from this process, particularly when addressing major safety risks such as heat stress.

Further guidance material on ways to manage working in hot environments can be obtained from Safe Work Australia at www.safeworkaustralia.gov.au and Queensland Workplace Health and Safety at www.worksafe.qld.gov.au

Authored by Sunwater, Health Safety and Environment Team, Fairbairn Dam

Environment

- Queensland, as a jurisdiction, endorses embedding the consideration of animals (pets and assistance animals) into disaster planning, in accordance with the Animal Care and Protection Act 2001.[212]
- Community education, awareness and engagement programs should also inform residents of their responsibilities for their pets during a heatwave event. These responsibilities may also be articulated to the community during a heatwave to ensure understanding and minimise confusion and anxiety.[213]

Response

Essential infrastructure

- Electricity network demand management programs act to reduce pressure to maintain system reliability during periods of high network demand.[214]
- Reliable telecommunications are essential during a heatwave, even more so when heatwave contributes to complex hazard events. Telstra can redirect telecommunications traffic if a facility or transmission line fails or is damaged. This may occur automatically or can be invoked manually if necessary.[215]

Access and resupply

- Mobile track gangs with water can be used to cool rail tracks during hot weather to prevent buckling.[216]
- Speed restrictions or closures of road and rail infrastructure may be used to prevent infrastructure damage.

Community and social

- Allocation and opening of 'cool places of refuge' for the community during an event will provide a shelter of last resort to those most vulnerable in the community. Cooling centres require adequate seating, medical support, food supplies, toileting, accessible drinking water and security. Securing redundancy of power and water supply in the event of possible widespread power outages should be considered when allocating communal infrastructure, such as libraries or community centres, to this role.
- In addition to the information provided by QH, as outlined below, existing community information networks should be used to reinforce key messaging. 'Disaster Dashboards' and social media channels operated by many councils are a good first point of information for community to access authoritative information on the event.
- Trusted entities within the community, such as church or community groups, are an excellent resource for disseminating information to socially isolated or vulnerable persons not covered by a health or care provider during an event.
- Queensland Fire and Emergency Services will increase bushfire monitoring during the event. This may see pre-deployment of assets into areas with high wildfire alert levels (WALs) to reduce response times.
- Building design may allow for the concentrated cooling of one room within the building as a refuge during heat events, much in the same way a household may have a bushfire or cyclone refuge.

Medical

- Disseminate public information and messaging released by QH, which expands on the following key messages:
  - have a plan
  - stay hydrated
  - stay out of the sun
  - keep cool
  - check on and look after others.
- The risk of adverse clinical effects from the heat can be minimised by encouraging people to:
  - drink plenty of water and monitor themselves for signs of dehydration (e.g. dark urine)
  - minimise physical activity
  - check on those at higher risk
  - check if their home air conditioner works before a heatwave, or go to a public area which has air conditioning if they don't have access at home
  - plan around the heat and avoid being outside between 11.00am and 3.00pm
  - avoid alcoholic, hot and sugary drinks
  - take cool showers or baths
  - wear light-coloured, loose-fitting clothes made from natural fibres
  - cool the house by shading windows and shutting curtains, and opening windows at night, if it is safe to do so.
- See the Case study: Putting people first – managing the human health impacts of heatwave on page 57 for more advice on medical and health response measures.

Significant industry

- Report any aquaculture disease or mortality to Biosecurity Queensland on 13 25 23. The Department of Agriculture and Fisheries provides free diagnostic services for any suspected disease events.[217]

Environment

- Phone the Department of Environment and Science on 1300 130 372 to report wildlife incidents, sick, injured or orphaned cassowaries or crocodiles. For sick, injured or orphaned wildlife (other than crocodiles and cassowaries) and reporting an sick, injured or dead turtle, dugong, dolphin or whale, telephone RSPCA Queensland on 1300 ANIMAL (1300 264 625).
- Report any fish kill incidents through the Department of Environment and Science hotline[218] on 1300 130 372.
- Encourage people to leave bowls of clean water out for wildlife in shady locations, protected from predators and pets. Shallow dishes are better for smaller animals. Unless advised to do so by a registered wildlife carer or veterinarian, people should not attempt to feed wild animals.
- Arrange for water sprinkling systems to be established around colonies of heat stressed birds and flying foxes.
- Develop procedures that identify roles and responsibilities for environmental response. This should clarify who is responsible for providing care for heat stressed animals, and for collecting and disposing of deceased animals following heat-related mass deaths.

Case study: Putting people first – managing the human health impacts of heatwave

Under the Queensland State Disaster Management Plan 2018, Queensland Health (QH) is the primary responsible agency for heatwaves. This includes responsibility for:

- developing and maintaining State and local heatwave planning arrangements
- maintaining business continuity and contingencies for prolonged power outages, loss of mains water supply or cooling systems and potential staffing impacts
- undertaking health related risk assessments where impacts on utilities are significant
- provision of health risk advice to stakeholders
- information sharing with health networks, local governments, stakeholder agencies and the community to address emerging public health risks
- identification and consideration of vulnerable groups in arrangements and communications
- developing community health messaging as part of a broader strategy
- supporting hospitals in the care and safety of staff, patients and the community, including resupply of vaccines.

Prevention and preparedness

Mitigation activities focus on activities that can prevent exposure to the effects of heatwaves. Examples include:

- design improvements to infrastructure to better allow heat management strategies
- ensuring prepared communities and response agencies have appropriate arrangements in place to manage human health impacts
- a clear understanding of the heatwave hazards, and any potential interaction with vulnerable elements, which may include reducing exposure to heatwaves, such as rescheduling public events.

QH as the primary agency for heatwave, reviews and provides communications to the public relating to the health impacts of heatwaves. QH also works in partnership with the whole of government to develop management strategies for both the Queensland community and other government and non-government organisations.

Community education and engagement strategies include:

- heatwave preparedness advice (e.g. self-management of heat stress, recognition of heat illness and food safety) in summer preparedness campaigns
- development and provision of targeted information for vulnerable groups and those who support, or care for, people at risk of serious health effects from heat
- provision of advice sheets for the public, Hospital and Health Services (HHSs) and other government and non-government agencies.

Heatwave preparedness activities are integrated with summer season preparedness activities, which are common across all organisations involved in Queensland's disaster management arrangements. These activities include:

- activating weather monitoring systems for the summer period and reviewing the previous season's monitoring and warning systems
- assessing resource capability for a heatwave response based on the potential increase in demand for services
- reviewing business continuity plans in case of interruption to services.

Response

The overarching human health response strategy for heatwave has five main elements:

1. reducing harm to patients and the community, and reducing impacts on the health system, through a proactive and scalable messaging campaign
2. identifying vulnerable groups and ensuring scalable support strategies are in place
3. managing demand on services linked to usual surge strategies
4. managing public health impacts due to effects on infrastructure, particularly impact on power generation
5. business continuity planning to ensure health services are maintained.

The first two actions are specific to heatwave with scale of response linked to the levels of heatwave as defined by the Bureau of Meteorology's (BoM's) Heatwave Service. The different levels of heatwave (low intensity, severe and extreme) with increasing risk profiles enable the generation of tiered arrangements to manage heatwaves with defined activation triggers and escalating response levels.

QH, in consultation and collaboration with the BoM, HHSs, the Queensland Ambulance Service (QAS), other key stakeholder agencies, and the State Disaster Coordination Centre (when activated), will establish briefings, provide consistent information for public messaging and advice for other agencies.

These may include other emergency services, disaster management groups, St John Ambulance (Qld), the Pharmacy Guild, the Royal Australian College of General Practitioners, the Commonwealth Department of Health regarding aged care facilities and the Australian Red Cross, as well as other non-government organisations with a community care focus. Through these networks, and through HHSs and Primary Health Networks, aged care facilities, private hospitals, community health care providers and pharmacies, QH can ensure identification and distribution of messaging to vulnerable groups across Queensland.

QH will also monitor and provide advice on the public health risks associated with effects of heat on infrastructure, particularly if power generation is affected. Arrangements are also in place to provide additional resources to hospitals as needed to ensure ongoing care of the community. Hospitals have plans in place to manage any potential surge of patients and consider specific clinical pathways and management plans for high risk groups.

Public information and messaging

The QH public communication strategy consists of five key messages that are consistently delivered to the community:

1. have a plan
2. stay hydrated
3. stay out of the sun
4. keep cool
5. check on and look after others.

The cornerstones of management of the clinical effects of heat exposure consist of rehydration and cooling. Most people can manage within their own immediate environment. However, it is important that people either create a cool environment (via air conditioning, use of fans or other means) or move to a cool environment (e.g. shopping centres and cinemas). The risk of adverse clinical effects from the heat can be minimised by encouraging people to:

- drink plenty of water and monitor themselves for signs of dehydration (e.g. dark urine)
- minimise physical activity
- check on those at higher risk
- check if their home air conditioner works before a heatwave, or go to a public area which has air conditioning if they don't have access at home
- plan around the heat and avoid being outside between 11.00am and 3.00pm
- avoid alcoholic, hot and sugary drinks
- take cool showers or baths
- wear light-coloured, loose-fitting clothes made from natural fibres
- cool the house by shading windows and shutting curtains and opening windows at night, if it is safe to do so.

The following societal groups are at substantial risk of increased morbidity and mortality during heatwaves and should be directly targeted by public messaging and education:

- the aged and frail, especially those living alone
- babies and young children
- pregnant and lactating mothers
- the obese
- people who live in urban areas ('heat islands')
- people who normally live in cool climates (e.g. tourists)
- people who are socially or geographically isolated, including the homeless and those from a non-English speaking background
- people with physical disabilities, cognitive impairment or mental illness that impairs their mobility or capacity to self-manage
- people working outside, especially involving physical exertion or sport
- people taking certain types of medications, including some illicit ones (these may include but are not limited to: allergy medications [such as antihistamines], some blood pressure and heart medicine [such as beta blockers/ vasoconstrictors], anticonvulsants, thyroid medications [such as thyroxine], diuretics, antidepressants and antipsychotics, alcohol and illicit drugs [such as amphetamines])
- people with chronic diseases such as heart disease, high blood pressure, diabetes, cancer or kidney disease
- people with acute illness or infections that cause dehydration or fever
- people with conditions that impair sweating, including skin disorders, congenital impairment of sweating, cystic fibrosis, quadriplegia and scleroderma.

Belonging to more than one at risk group may significantly increase the risk to that individual of heat illness, since several of the risk factors may increase the effect of others.

As previously mentioned, should the extreme heat impact on critical infrastructure, such as electricity supply, then certain groups become especially vulnerable including:

- those who rely on electricity to power medical devices, such as ventilators and dialysis machines in their homes
- those who are reliant on medications that require refrigeration, such as insulin.

Authored by Health Disaster Management Unit, Queensland Health

Recovery

Essential infrastructure

- Unless a major network outage has been sustained as a result of a heatwave or heatwave associated event, recovery from localised outages (for power and communications) will be delivered within normal network management processes.

Access and resupply

- Replacing damaged surfaces with pavement that is more resilient to extreme temperatures – 'cool paving' – will reduce long-term costs and increase operational efficiency during heatwaves.

Community and social

- Despite the risk to community, high levels of tangible and intangible losses, and connection to other natural disasters such as bushfires, the impacts from severe and extreme heatwaves do not fall under the definition of an eligible disaster as outlined within the Natural Disaster Relief and Recovery Arrangements.[219]
- Therefore, any losses sustained during severe and extreme heatwave events, such as those outlined within this assessment, will likely be borne by individual businesses due to an absence of Federal relief and recovery funding.

Medical

- The Queensland Health Heatwave Sub-Plan includes the following considerations for recovery:
  - Addressing the health impact of heatwaves on vulnerable community members especially those with existing chronic disease who may need ongoing access to hospital or community care during their recovery.
  - Mental health impacts are likely to be sustained, as with any disaster, especially when there have been economic, social or personal losses.

Significant industry

- Encourage support of local businesses affected by heatwave events through the 'Go Local, Grow Local' initiative. This initiative aims to help Queensland businesses promote their products and services, encourages Queenslanders to support small businesses in their community, and supports communities affected by natural disasters.[220]

Environment

- Identify and monitor actual and potential impacts on the environment and the associated recovery operations, and provide strategic advice to inform recovery efforts.
- Identify, advocate and pursue cross-sector recovery solutions that will achieve multiple objectives, including reducing future impacts on the environment, through the use of natural safeguards and environmentally resilient design (Figures 21 and 22).

Figure 21: View of the Cavenagh Street cooling vine covered shade structure under construction in Darwin, NT. Source: Foreground

Figure 22: Artists impression of the mature vine covered shade structure in Darwin, NT. Source: NT News

SUMMARY

Summary

Within the State Natural Hazard Risk Assessment 2017, the risks associated with heatwaves were accorded the third highest priority from the seven natural hazards assessed. Heatwaves, it was acknowledged at the time, were likely to have been underestimated in terms of impact and consequences across all sectors of the community due to their less violent, slower onset and less publicised nature.

This subsequent assessment has proven that hypotheses correct – with some exceptions, there is a broad underestimation of the risks associated with heatwaves and heat events within disaster management, business continuity and climate adaptation planning across Queensland. This is consistent with heatwave's growing reputation as a 'silent killer'.

The aim of this assessment is to increase the understanding and awareness of the current and future risks and impacts of heat events, heatwaves, and associated hazards. The challenges outlined below reflect the key findings of this assessment, and should be considered as a guide for further study, discussion and future planning against heatwave related risk.

Six main challenges that can be addressed to help manage our increasing heatwave risk in Queensland were identified:

1. Increasing urbanisation, an absence of climate-based building codes for local contexts, and a lack of urban designs that can adequately manage the increasing exposure of urban populations to urban heat island effect (UHIE).
2. This is further exacerbated by increasing loss of urban canopy cover, green spaces and lack of support for using 'green infrastructure' components of urban planning and design to improve the management of heatwaves and UHIE within Queensland.
3. Community education of the current and future risks posed by heatwaves continues to lag behind education initiatives and campaigns for events that are less frequent but more visible, such as cyclones, floods and bushfires.
4. Aging populations in areas projected to experience higher rates of heatwave occurrence are expected to increase pressure on health, aged care and community services. This is likely to be acute within regional communities projected to experience the highest increases in heatwave occurrence.
5. Increasing heatwave occurrence in regions already experiencing water stress and/or prolonged drought conditions will exacerbate issues currently facing many rural Queensland communities. Agricultural losses during heatwave events are projected to increase markedly unless robust government policy initiatives that enable the sector to transition sustainably can be rapidly implemented.
6. Adaptation strategies for individuals and communities against increasing climate related risks such as heatwaves are currently not widely accessible. This is compounded by a lack of understanding within at-risk communities of suitable adaptation strategies and their benefits. Increasing access to cost effective solutions that increase community and household resilience to heatwaves is a key challenge facing many local governments throughout Queensland and, indeed, Australia.

Considering the above challenges, the assessment of current and future risk potential, and additional information outlined in this assessment, the following areas of Queensland are considered be at highest risk from future heatwave and heat events:

1. *Regional communities located within the tropical region of Far North Queensland including those of Cairns, Etheridge, Mareeba, Douglas, Wujal Wujal and Cooktown. This assessment reflects the current heatwave potential within the region and the projected increase in heatwave frequency to the end of the 21st century.*

   It also acknowledges the changing nature of the communities within Far North Queensland which are growing in both age and population. As an example, Cairns has the fourth fastest growing population of those aged over 65 in Queensland behind the Wide Bay, Sunshine Coast and Darling Downs regions.

   This assessment also accounts for the challenges presented to the environment and ecosystems within Far North Queensland, which links to the regional economy. These sectors are at significant risk from increasing bushfire potential, increasing occurrences of mass-deaths of native wildlife populations and exacerbation of the risk to the survival of the Great Barrier Reef.

   Of note, Aboriginal communities located within Far North Queensland are projected to experience the highest rate of increase in heatwave frequency per local government area (LGA); with communities such as Napranum and Torres Shire experiencing over 250 days per year in heatwave conditions by 2090.

2. *Communities within the Central and Western regions of Queensland such as those within Central Highlands and Longreach.*

   This analysis identifies potential impacts to communities located within this region from some of the highest rates of increase in both heatwave frequency per LGA and average temperatures; days above 35˚C are projected to double across the region by 2090.

   This expected increase also coincides with projected increases in drought occurrence and general water stress, and a declining population base across many western regional communities.

   Given that many of these communities are involved in or support the agricultural sector, subsequent impacts to this sector from increasing temperatures and heatwave occurrence will likely compound impacts to the communities in the future.

3. *Communities within and surrounding the Greater Brisbane region such as Moreton Bay, Ipswich, Logan, Lockyer Valley and Scenic Rim.*

   This analysis reflects the challenges posed by the significant increase in projected population growth, associated urbanisation, inadequate building designs, and UHIE potential within the region. Many of these areas have some of the lowest levels of urban canopy coverage within Queensland and loss rates are increasing as further areas are cleared for development.

> Importantly, the assessment also found a low level of awareness among the public on how to manage the risks posed by heatwaves due to an increasing reliance on active cooling methods such as air conditioning within homes, offices and social infrastructure.

Despite according these areas highest priority in terms of heatwave risk potential, the increasing risk to other areas within Queensland should not be discounted.

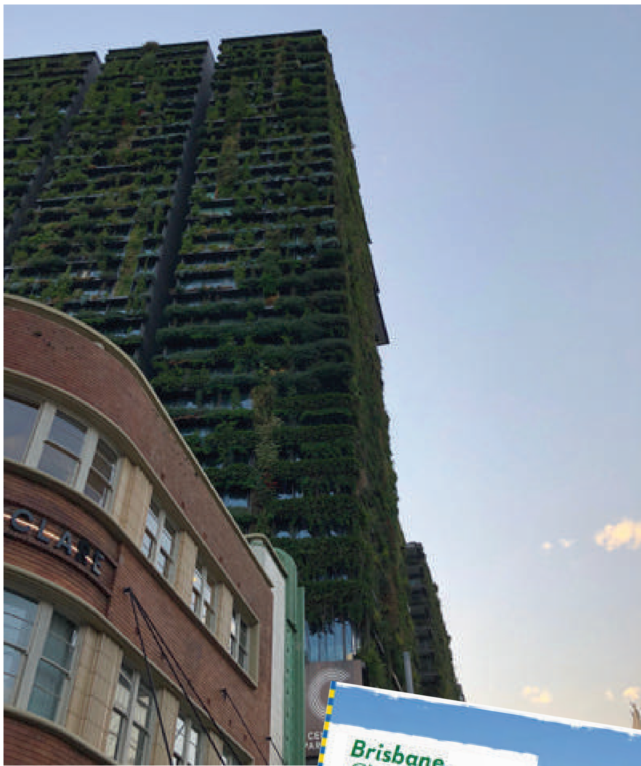
It is important to reflect that whilst prevention, preparedness and response to heatwaves as a hazard will primarily focus on human health, there is an immediate and growing need for a coordinated multi-agency approach at all levels of Queensland's disaster management arrangements. This reflects the findings of this assessment, which has highlighted cross sectoral impacts from heatwaves, and therefore the need for a coordinated approach to address the changing nature of heat events and heatwaves under the influence of climate change.

Future iterations of this assessment and other associated studies will continue to explore this risk in greater detail and, as a result, better define Queensland's risk from heatwaves and associated hazards.

If further research, analysis or assessment is required after reviewing this document to understand the heatwave risk for a particular area, a collaborative approach with the stakeholders listed below is recommended to ensure consistency in evaluating the hazard in line with State and national assessments.

Key agencies:

- Queensland Fire and Emergency Services (Hazard and Risk Unit)
- Queensland Health
- Department of Environment and Science
- Bureau of Meteorology.



The above images highlight examples of strategies that aim to deal with the increasing risks associated with heatwaves and urban heat island effect (UHIE) using 'green infrastructure'. Clockwise from bottom left:

- Image of the extensive canopy cover present at the Eumundi Markets, Queensland. This canopy is maintained to provide respite and protection from the heat for the thousands of visitors to this popular tourist destination. Source: Queensland Fire and Emergency Services
- Artist rendering of Melbourne as a 'green city'. Under the Melbourne Urban Forest Strategy, Melbourne City Council seeks to increase public realm canopy cover from 22% at present to 40% by 2040. Source: Melbourne City Council
- Image of the vertical hanging gardens at One Central Park in Sydney's CBD. This vertical garden is designed to improve the air quality and thermal efficiency of the building. It uses only recycled water to care for the 85,000 plants that make up the vertical garden. Source: Queensland Fire and Emergency Services
- Brisbane. Clean, Green, Sustainable 2017-2031. This strategy highlights how Brisbane City Council will deal with climate related risks through a multi-sector approach. Chapter 8 details the use of 'Urban Forestry' to improve air quality and reduce the risks associated with UHIE. Source: Brisbane City Council

Glossary

Adaptation
The steps governments, businesses, communities and individuals take to deal with risks from climate change impacts.

Adaptive capacity
The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Anthropogenic climate change
Any significant change in the measures of climate lasting for several decades or longer, including changes in temperature, precipitation, or wind patterns. Historically, the Earth's climate has changed over time but there is strong scientific consensus that the recent observed changes, over the past 50 years or so, have been primarily caused by human activities.

Capability
The combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce risks and strengthen resilience. Capability may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.

Capacity
A subset of capability, referring to the ability to sustain that effect for a designated period.

Climate
Climate relates to the average weather over a period of months to thousands or millions of years.

Climate change mitigation
Climate change mitigation includes actions taken globally, nationally and individually to limit changes in the global climate caused by human activities. Mitigation activities are designed to reduce greenhouse emissions and/or increase the amount of greenhouse gases removed from the atmosphere.

Climate change projections
A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models.

Climate change vulnerability
The degree to which a system or group is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a result of the type, magnitude, and rate of climate variation to which a system or group is exposed, its sensitivity, and its ability to adapt.

Climate legal risk
Climate legal risk is the risk of exposure to legal action that accompanies a decision that relates to climate change impacts. It encompasses the above elements of factual and legal uncertainty, and specifically concerns the risk arising from legal duties and obligations as they relate to the impacts of climate change.

Climate risk
The potential for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services), and infrastructure.

Community Resilience
Community resilience entails the ongoing and developing capacity of the community to account for its vulnerabilities and develop capabilities that aid that community in (1) preventing, withstanding, and mitigating the stress of a natural disaster event; (2) recovering in a way that restores the community to a state of self-sufficiency and at least the same level of functioning after a natural disaster event; and (3) using knowledge from a past response to strengthen the community's ability to withstand the next disaster event.

Compound Extreme
The simultaneous or sequential occurrence of multiple extreme events at singular or multiple locations

Consequence
The outcome or impact of an event and may be expressed qualitatively or quantitatively. There can be more than one consequence from an event. Consequences are generally described as the effects on people, society, the environment and the economy.

Disaster
A serious disruption in a community, caused by the impact of an event, that requires a significant coordinated response by the State and other entities to help the community recover from the disruption.

Disaster Management
Arrangements about managing the potential adverse effects of an event, including, for example, arrangements for mitigating, preventing, preparing for, responding to and recovering from a disaster.

Disaster Resilience
The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Downscaling
Downscaling climate data is a strategy for generating locally or regionally (10 to 100km) scaled data from larger Global Circulation Models (GCMs).

El Niño
El Niño is the warming of the oceans in the equatorial eastern and central Pacific. Over much of Australia, El Niño brings drought. See also El Niño Southern Oscillation below.

El Niño-Southern Oscillation (ENSO)

(ENSO) Refers to widespread 2–7-year oscillations in atmospheric pressure, ocean temperatures and rainfall associated with El Niño (the warming of the oceans in the equatorial eastern and central Pacific) and its opposite, La Niña. Over much of Australia, La Niña brings above average rain, and El Niño brings drought.

Emergency

An event, actual or imminent, that endangers or threatens to endanger life, property or the environment, and requires a significant and coordinated response. In some jurisdictions emergency is interchangeable with disaster.

Emergency Management Sector

Includes any organisation (Government or Non-Government) that contributes to Emergency Management activities across Prevention, Preparedness, Response and Recovery and operates within Queensland's Disaster Management Arrangements (QDMA).

Exposure

The elements within a given area that have been, or could be, subject to the impact of a hazard. Exposure is also sometimes referred to as the 'elements at risk'.

Hazard

Refers to any potential occurrence of a natural or human-induced physical event that may cause damage to property, infrastructure, livelihoods, service provision, environmental resources etc.

Heatwave

Three days or more of high maximum and minimum temperatures that are unusual for that location.

La Niña

La Niña is the cold phase of the El Niño-Southern Oscillation (ENSO). The ENSO is basin-wide warming of the tropical Pacific Ocean east of the dateline associated with fluctuation of a global-scale tropical and subtropical surface pressure pattern, the Southern Oscillation.

Level of Risk

Magnitude of a risk, or a combination of risks, expressed in terms of the combination of exposure, vulnerability, consequence and their likelihood.

Maladaptation

A maladaptation is defined by the IPCC (2014) as 'an action that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future'. More precisely, maladaptation is an action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups.

Preparedness

Arrangements to ensure that, should an emergency occur, all the resources and services that are needed to cope with the effects can be efficiently mobilised and deployed.

RCP

The Representative Concentration Pathways (RCP) are the results of four separate integrated assessment model simulations. They were selected and defined by their total radiative forcing (cumulative measure of human emissions of GHGs from all sources expressed in Watts per square meter) pathway and level by 2100. The RCPs were chosen to represent a broad range of climate outcomes, based on a literature review, and are meant to serve as inputs for climate modelling. The RCPs are not forecasts nor are they policy recommendations.

Residual Risk

The risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained.

Risk Assessment

An approach to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

Risk Identification

The process of finding, recognising and describing risks. Risk identification involves the identification of risk sources, events, their causes and their potential consequences. Risk identification can involve [the use of] historical data, theoretical analysis, informed and expert opinions and stakeholders' needs.

Vulnerability

The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

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Sensors were placed close to people using the street – e.g. footpaths and pedestrian crossings – to collect microclimate data that correspond to people's experience at the street level. Sensors are at times placed in the shade (under awnings, for instance) and at times in the sun (in traffic lights adjacent to pedestrian crossings) in a height that varies between 2,15 and 3,33 metres.

Sensors used have an accuracy of ~0.40C for air temperature and ~3% for humidity. Data collection started in May 2018 and will continue until May 2020, for a minimum period of two years.

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Appendices

Appendix A: Historical and projected changes in heatwave frequency by Local Government Area (1998-2090)

Historical Annual Heatwave Count (days)			Projected Maximum Annual Heatwave Count (days) relative to 1986-2005 Baseline			
Local Government Area	1998-2008	2008-2018	2030	2050	2070	2090
AURUKUN SHIRE	31	40	17	71	168	242
BALONNE SHIRE	24	31	11	26	46	71
BANANA SHIRE	26	27	11	31	64	104
BARCALDINE REGIONAL	22	27	13	32	62	100
BARCOO SHIRE	25	32	12	28	49	73
BLACKALL TAMBO REGIONAL	23	26	12	30	57	90
BOULIA SHIRE	22	29	12	27	53	81
BRISBANE CITY	23	29	22	52	93	125
BULLOO SHIRE	27	33	11	24	40	61
BUNDABERG REGIONAL	23	25	23	54	94	126
BURDEKIN SHIRE	21	20	26	64	118	155
BURKE SHIRE	19	33	31	83	145	183
CAIRNS REGIONAL	28	26	26	72	129	167
CARPENTARIA SHIRE	31	35	19	67	145	199
CASSOWARY COAST REGIONAL	22	25	28	74	129	164
CENTRAL HIGHLANDS REGIONAL	26	25	16	40	75	114
CHARTERS TOWERS REGIONAL	20	23	13	44	101	145
CHERBOURG ABORIGINAL SHIRE	17	18	9	26	52	88
CLONCURRY SHIRE	18	33	13	29	57	93
COOK SHIRE	39	57	45	104	196	255
CROYDON SHIRE	19	23	13	30	71	126
DIAMANTINA SHIRE	24	32	12	27	46	70
DOOMADGEE ABORIGINAL SHIRE	15	21	20	64	129	176
DOUGLAS SHIRE	27	21	24	70	137	176
ETHERIDGE SHIRE	22	22	13	35	82	137
FLINDERS SHIRE	21	26	13	32	63	104
FRASER COAST REGIONAL	25	23	24	55	96	129
GLADSTONE REGIONAL	24	27	23	56	97	130
GOLD COAST CITY	22	24	21	51	90	123
GOONDIWINDI REGIONAL	26	31	10	26	49	79
GYMPIE REGIONAL	24	24	25	57	98	131
HINCHINBROOK SHIRE	21	18	28	69	124	160
HOPE VALE ABORIGINAL SHIRE	21	33	45	100	165	208
IPSWICH CITY	20	22	10	29	59	94
ISAAC REGIONAL	24	24	27	63	107	138
KOWANYAMA ABORIGINAL SHIRE	31	35	18	69	149	204
LIVINGSTONE SHIRE	22	16	26	61	106	139
LOCKHART RIVER ABORIGINAL SHIRE	29	34	29	89	167	226
LOCKYER VALLEY REGIONAL	20	22	10	28	58	93

Historical Annual Heatwave Count (days)			Projected Maximum Annual Heatwave Count (days) relative to 1986-2005 Baseline			
Local Government Area	1998-2008	2008-2018	2030	2050	2070	2090
LOGAN CITY	21	24	17	43	81	116
LONGREACH REGIONAL	21	28	13	32	58	83
MACKAY REGIONAL	22	22	27	65	111	146
MAPOON ABORIGINAL SHIRE	30	42	23	83	186	255
MARANOA REGIONAL	26	28	12	29	59	96
MAREEBA SHIRE	24	23	18	67	131	171
MCKINLAY SHIRE	18	28	14	31	58	89
MORETON BAY REGIONAL	20	24	22	53	93	125
MORNINGTON SHIRE	19	17	37	97	160	196
MOUNT ISA CITY	19	32	13	29	60	97
MURWEH SHIRE	25	30	12	29	56	91
NAPRANUM ABORIGINAL SHIRE	31	41	21	78	178	252
NOOSA SHIRE	22	23	24	54	95	128
NORTH BURNETT REGIONAL	22	24	11	31	65	104
NORTHERN PENINSULA AREA REGIONAL	25	38	23	80	169	235
PALM ISLAND ABORIGINAL SHIRE	16	16	26	68	117	149
PAROO SHIRE	26	32	11	25	43	66
PORMPURAAW ABORIGINAL SHIRE	32	36	19	74	157	212
QUILPIE SHIRE	26	33	13	29	52	78
REDLAND CITY	22	27	21	51	91	123
RICHMOND SHIRE	20	26	14	32	59	100
ROCKHAMPTON REGIONAL	24	20	21	53	95	127
SCENIC RIM REGIONAL	20	23	11	31	64	100
SOMERSET REGIONAL	19	23	10	31	63	99
SOUTH BURNETT REGIONAL	21	21	10	28	55	92
SOUTHERN DOWNS REGIONAL	20	23	10	28	58	92
SUNSHINE COAST REGIONAL	20	24	24	54	95	127
TABLELANDS REGIONAL	21	19	12	47	106	150
TOOWOOMBA REGIONAL	25	26	10	28	54	89
TORRES SHIRE	55	92	33	113	205	257
TORRES STRAIT ISLAND REGIONAL	49	80	33	113	205	257
TOWNSVILLE CITY	21	18	24	63	113	156
WEIPA TOWN	28	41	17	71	168	242
WESTERN DOWNS REGIONAL	26	28	12	29	56	91
WHITSUNDAY REGIONAL	23	24	27	65	113	153
WINTON SHIRE	18	29	13	31	57	85
WOORABINDA ABORIGINAL SHIRE	26	21	10	29	57	96
WUJAL WUJAL ABORIGINAL SHIRE	18	20	10	47	113	166
YARRABAH ABORIGINAL SHIRE	24	21	24	72	129	166

Appendix B: Mapping the future – the Queensland Future Climate Dashboard

Understanding the need to provide reliable regional scale simulations of future climate, the Science Division from the Department of Environment and Science (DES) developed the Queensland Future Climate Dashboard, which summarises information from 11 state-of-the-art climate models with regional scale simulations (10-kilometre grid cells) until 2099.

By facilitating easy access to this data, DES hopes to support climate adaptation policies and management.

The dashboard is an online visualisation platform composed of drop-down menus, maps, plots and tables, so users can customise, visualise and export summarised future climate information according to their region or interest[221] (see Figure I below).

This higher spatial resolution means that regional climate models can consider local biophysical properties such as topography, vegetation and land-sea contrast, and better simulate local climate as a result. In addition, Queensland's future climate simulation provides continuous projections until the end of the century, rather than previously used time windows.

WHAT?	WHO?	WHERE?
Summary statistics	General public, stakeholders and policy makers	Dashboard
Regional reports	Farmers, regional natural resource managers and decision-makers	Dashboard
Timer-series	Utility and infrastructure managers and planners, other non-spatial scientists, statisticians	Dashboard
Gridded and Vector datasets	Climatologists, hydrologists, ecologists, agriculturalists, natural resource managers, spatial modellers and other spatial data spatialists	TERN (netcdf) dashboard (shapefile)

Figure I: Data availability from the Future Climate Dashboard highlighted against potential users. Source: Department of Environment and Science

The Queensland Future Climate Dashboard provides high resolution simulations for 30 different metrics grouped in six climate themes:

1. mean climate
2. heatwaves
3. extreme temperature indices
4. extreme precipitation indices
5. droughts
6. floods.

The information for regional projections was spatially aggregated from 10 kilometre pixel-size grids to specific regions. The five specific regions in which projections are presented are:

1. local government areas
2. Regional Plan areas
3. bioregions
4. major river basins
5. disaster districts.

In addition, users can visualise and download future climate data across calendar seasons, wet and dry periods and years. Information is summarised for four 20-year time slices centred in 2030, 2050, 2070 and 2090.

The Queensland Future Climate Dashboard offers a fully interactive interface where users can customise maps and plots, as well as download summary statistics, screenshots and spatial data for different purposes, such as local and regional planning, biodiversity management, water management and emergency services. By combining cutting-edge high-resolution climate models and latest trends in big data visualisation within an interactive platform, DES expects to bridge climate science and adaptation through an easy-to-use platform for end users (see Figure II)

The major purpose behind constructing these data sets is to aid in decision making in an environment of uncertainty.[222] This is often referred to as climate change risk assessment. Climate risk is the product of the consequences of climate change and the likelihood of those consequences.

The risk assessment methodology within the Queensland Emergency Risk Management Framework (QERMF) illustrates how climate change projections can be used in a risk assessment framework. The risk analysis considers likelihood of occurrence (L), vulnerability (V) and consequence or likely impact (C). The methodology put forward by the QERMF considers the climate risk obtained from both historical records and future projections.

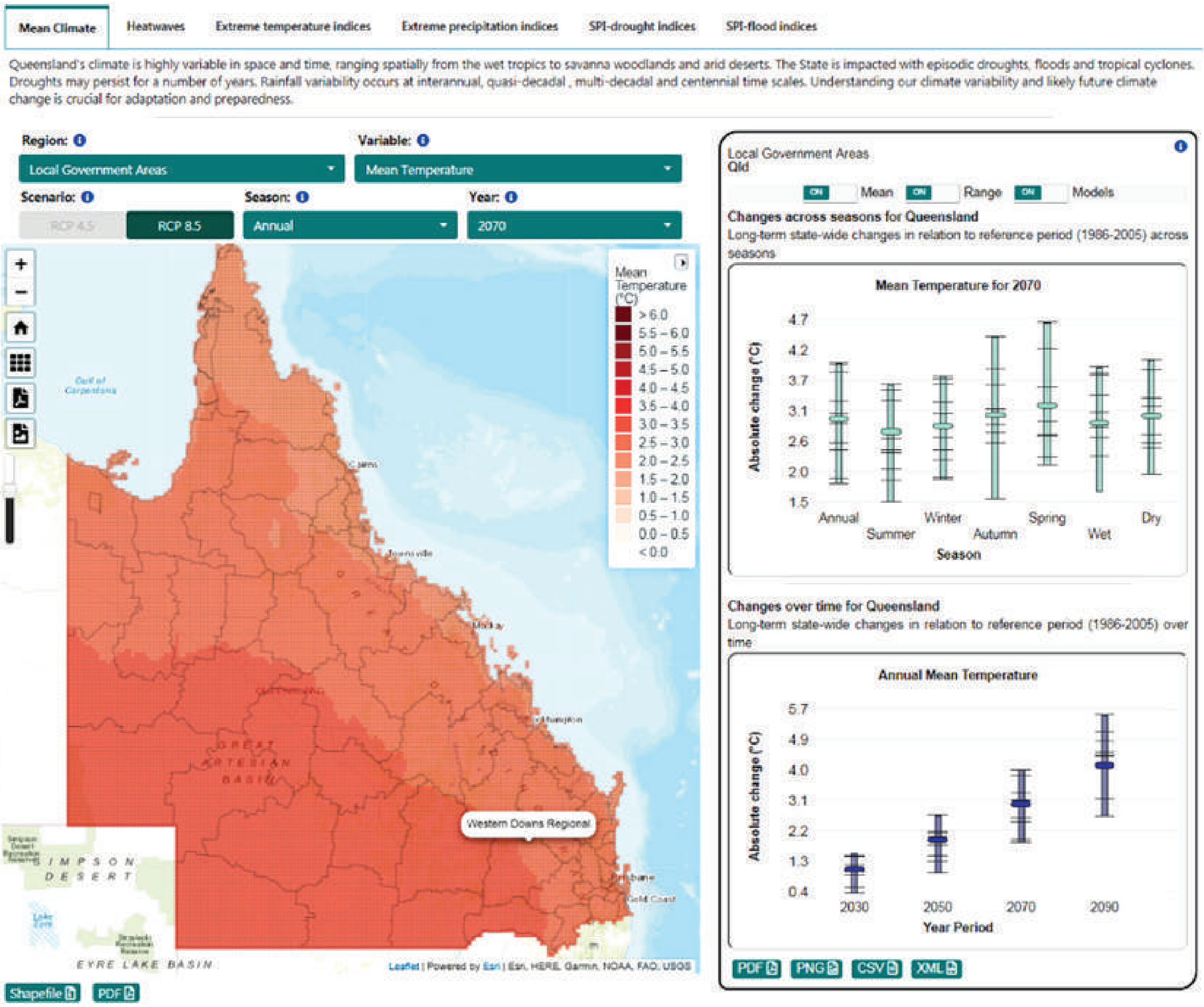


Figure II: Screenshot of the Queensland Future Climate visualisation dashboard. Source: Department of Environment and Science

Authored by Environmental Policy and Programs, and Climate Science Division, Department of Environment and Science

Appendix C: The Emergency Management Sector Adaptation Plan (EM-SAP)

Emergency Management Sector Adaptation Plan for Climate Change | fact sheet

The Queensland Government Climate Change Response

To address the future climate outlook, the Queensland Government released the Queensland Climate Adaptation Strategy (Q-CAS) in July 2017, which is being led by the Department of Environment and Science (DES). The aim of Q-CAS is an innovative and resilient Queensland that manages the risks and harnesses the opportunities of a changing climate.

The Q-CAS has four pathways that seek to facilitate a holistic approach to climate adaptation with a total of 18 actions. The four pathways include People and Knowledge, State Government, Local Governments and Regions and, Sectors and Systems.

The development of eight Sector Adaptation Plans is part of the initial action under the Sectors and Systems pathway. They are intended to be high-level strategic documents that map the current status of climate change adaptation and identify climate adaptation priorities for each sector.

For more information on the Queensland Government's Climate Change Response, go to: https://www.qld.gov.au/environment/climate/response

The Emergency Management Sector Adaptation Plan (EM-SAP)

The Emergency Management Sector stands to be continually challenged by changes to the frequency, intensity, distribution and duration of acute events, major disasters and long-term climate related stresses. Importantly, the climate is already changing, and the need to incorporate climate change into the comprehensive approach across prevention, preparedness, response and recovery is paramount.

The EM-SAP provides a vision for the sector and a series of principles and priorities in order to achieve it. It is a plan developed by the sector for the sector, and relies on all stakeholders engaged in Queensland's Disaster Management Arrangements to actively contribute. By working together, the sector will be more effective and efficient at tackling the issues brought about by climate change.

This approach will enable Queensland to more deeply understand its current and future disaster risk, strengthening governance and investment in line with the Sendai Framework for Disaster Risk Reduction 2015-2030 and Sustainable Development Goal 13 for Climate Action. It also provides a platform for the Queensland Disaster Resilience Strategy commitment to 'identifying adaptation opportunities following disasters and in anticipation of climate change' and 'making Queensland the most disaster resilient state in Australia'.

Vision - *An adaptive emergency management sector that is fully engaged with the risks and opportunities of a changing climate, building resilience together with the communities of Queensland.*

Principles

11 principles have been identified to guide climate adaptation activities within the sector. Three principles (outlined below) have been developed specifically for the Emergency Management Sector, with remaining eight being adopted directly from the Q-CAS.

1. Adaptation should address the comprehensive approach to disaster management - prevention, preparedness, response and recovery.
2. Adaptation should be considered using a systems approach, ensuring that it is responsive to local conditions and the needs of the entire community.
3. Adaptation should address both acute major events and continuous incremental change.

Queensland Government

Emergency Management Sector Adaptation Plan for Climate Change | fact sheet

Priorities

The eight priorities identified within the plan seek to further engrain climate change into sector strategic investment and disaster management planning at all levels. Each priority within the plan has a rationale, identified actions, desired outcomes and associated challenges.

1. Sector-led awareness and engagement about climate change to increase the awareness and understanding of climate change science within the sector and the broader community.
2. Integration of climate change into sector governance and policy to align policy positions across the sector where possible and facilitate cross-sector planning.
3. Enhancing the sector's understanding of climate change risk and its ability to adapt to climate-related risks facing their organisations.
4. Research and development of new knowledge and supporting tools to support the consideration of climate change in sector decision making and planning.
5. Allocation of resources to support sector adaptation where measures have been identified.
6. Increasing the resilience of infrastructure critical to the sector and community through working closely with infrastructure providers and operators.
7. Promoting and enabling community resilience-building and self-reliance through the provision of enhanced climate change information to communities and guidance as to how they can be better prepared for expected impacts.
8. Volunteerism, volunteering and workforce management and exploring them through a climate change lens to understand and plan for the potential impacts on workforce health and availability.

For further information on the EM-SAP and the intended next steps for implementation, go to the 'Disaster Management Plans' section at www.disaster.qld.gov.au

Why wait? Immediate actions for sector stakeholders

Sector organisations should review the priorities and principles in their own organisational contexts and how they may be applied or included in planning processes.

QFES has already commenced examining methods to incorporate climate projections into the Queensland Emergency Risk Management Framework (QERMF) ensuring Queensland's Disaster Management Arrangements will be supported by contemporary and forward-looking climate science.

A suite of five case studies have been developed to demonstrate sector activities already underway in support of climate adaptation action. If you have a similar case study to share with the sector, please send an email to sdu@qfes.qld.gov.au

Further information

For further information on the Emergency Management Sector Adaptation Plan or Climate Change Information, please contact:

The QFES Sustainable Development Unit
sdu@qfes.qld.gov.au
(07) 3635 3282

Appendix D: Building design, urban design and urban planning – a guide for Local Government

There are two key mitigation strategies for heatwaves. The first is to decrease exposure to high temperatures, and the second is to manage the impacts of high temperatures.[223] Building design, neighbourhood urban design and broader regional planning all play a significant role in both these strategies.

The design, development and management of heat resistant urban environments is a complex challenge that requires context sensitive solutions, and cumulative action and consideration from a range of government, industry and community stakeholders. The approaches for mitigating the impact of heatwaves on building design and the built environment should be viewed as interdependent sets of controls and feedbacks.

These mechanisms must inform one another and provide a basis for sound urban development planning and policy, in addition to appropriate emergency and mitigation responses.[224]

Considering climate change and the increase of 'unprecedented' weather events, including heatwaves, improvement to the design and delivery of at-risk urban environments is needed. Often many of the climate impacts and subsequent considerations for building and urban design are neglected. The increasing risks associated with heatwaves in Queensland require attention to be given to the re-integration of climatic considerations into the development of existing and future communities in Queensland (see Figure I).

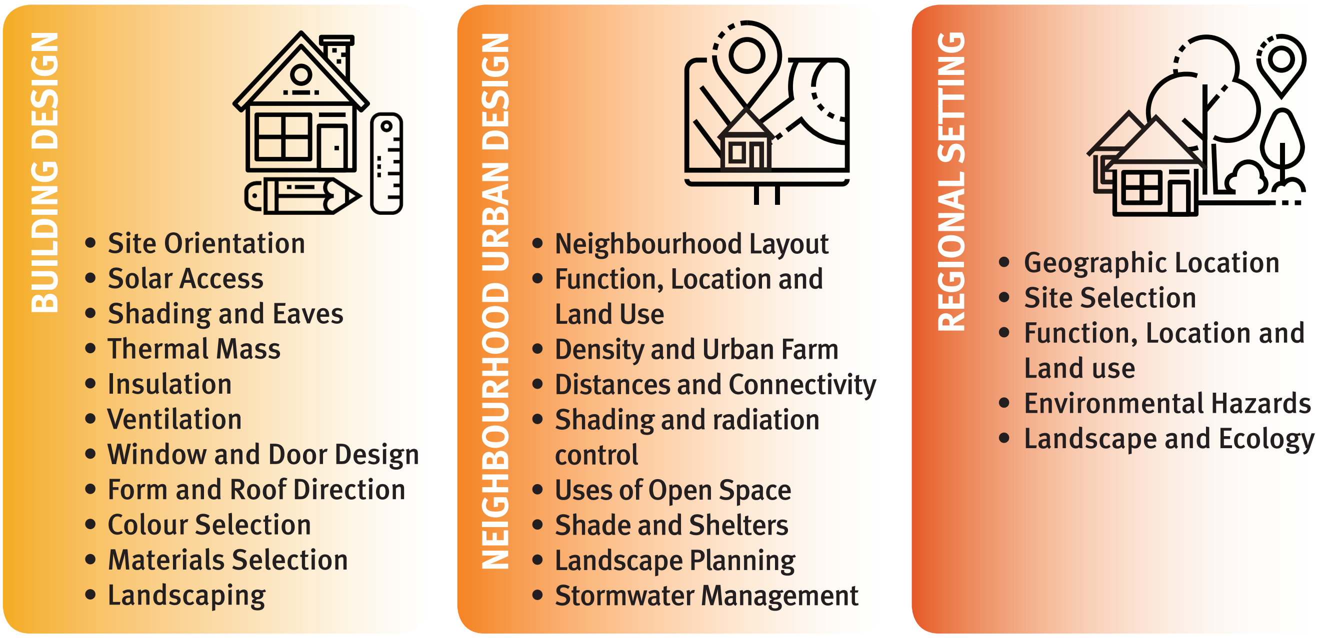


Figure I: Climatic impacts on building design, neighbourhood urban design and regional settlement patterns. Adapted from: Bitan (1988) and Koppe et al. (2004)

Adapting buildings to heat

Urban populations spend much of their time indoors, at home and at work. The indoor comfort temperature depends on the outdoor temperature. Most buildings have a comfortable indoor temperature range of between 18°C and 25°C.[225] In recent decades, rapid urbanisation has led to an increase in building design that does not provide such comfort without active means of temperature control. Populations in such buildings are less adapted and perhaps more vulnerable to heat episodes.[226]

The design of a building may increase occupant vulnerability to heat stress during a heatwave. For example, dark coloured roofing material absorbs solar radiation and transfers heat into the building.[227] Research suggests that many existing residential and commercial buildings in Australia are not designed for extreme heat events. This is because many older buildings in Australia are not adequately insulated to reduce heat transfer or to comply with national energy efficiency standards.[228]

The design of buildings, as well as their collective planning and development, is critical to managing and mitigating the range of impacts from extreme weather events, such as heatwaves.

Current observations of Australian building design include:

- Australia has seen a trend in increasing housing sizes (exceeding all other countries) and an accompanied increase in air conditioning systems to maintain thermal comfort.
- There is limited community and consumer knowledge of appropriate building design for heat resistance, with a reliance on air conditioning.[229]
- Such dependence is coupled with high electricity consumption charges and the potential for an overload of the electricity grid during heat events.[230]

- Careful consideration of the capacity of both new and existing residential electricity networks is required.[231] In those land subdivisions where larger houses on smaller lots are the norm, the potential to exceed the maximum demand that the electrical distribution network (local transformer) is capable of supplying exists.
- The high cost of adapting older building stock by either passive or active means of cooling often restricts implementation, while high electricity costs often mean vulnerable groups may not use air conditioning even if available.
- Building design may allow for the concentrated cooling of one room within the building as a refuge during heat events, much in the same way a household may have a bushfire or cyclone refuge.[232]
- The provision and promotion of safe, public places that are air conditioned and can be used as cooling centres (evacuation and respite centres) is essential.[233] Cooling centres require adequate seating, medical support, food supplies, toileting, accessible drinking water and security.[234]
- Government advice is available on how to reduce heat impacts in housing, government buildings and urban planning. The 'your home' website and guide at www.yourhome.gov.au is a key resource.[235] However, this and other such advice only presents guidelines with limited mandatory requirements.[236]
- The use of energy equivalence (building star) ratings is, however, a mandatory scheme introduced in 2011 to inform sustainable residential and commercial building design.

Building star ratings and heat resistance

The introduction of energy equivalence ratings is intended to *"improve the energy efficiency of the dwelling and to create a more naturally comfortable home"*.[237] This scheme is concerned with the design of the building shell – roof, walls, windows and floors – and is a rating out of 10 stars, with the higher number of stars indicating better performance.

Key passive design principles underpin the scheme and, as a result, it offers contributions to heat resistance. But that is not its purpose. Accordingly, there is the potential for confusion that the star rating scheme offers consumers a more heat resistant building, which is not the case.

Other key considerations include:

- To mitigate the effects of climate change, new buildings within Australia are required to meet an energy efficient target under the National Construction Code.[238] For example, government buildings in Queensland are required to meet a 5-star energy efficiency target under the National Australian Built Environment Rating System (NABERS).[239]
- In Queensland, new houses and townhouses (class 1 buildings) must achieve a minimum energy equivalence rating of 6 stars. Advice is provided for houses in each of Queensland's four climate zones under the Building Code of Australia (BCA).[240]
- A star rating of a building is no guarantee on the quality of the housing product and does not provide a representation of the heat resistance of the building design.
- Significant flexibility in achieving compliance exists. Indeed, while common practice, it is not a mandatory requirement of a building certifier to request a Building Form 15—Compliance Certificate for Building Design or Specification. Further, if requested, a Form 15 may be provided 'from a competent person' in good faith and the certifier may rely on this without further checking.[241]
- There is inconsistency in the building inspection and certification practices for residential dwellings.
- A dwelling's ability to be heat resistant and its energy efficiency performance is influenced by a range of active and passive design elements, including its location, orientation, materials, window size and type, and fixtures. A house design that may achieve a 6-star energy equivalence in one location may not in another.
- The Australian Building Code Board has stated that the National Building Standards will be improved to include heat reduction measures by May 2019.[242]
- Statutory Codes, Australian Standards and government policies related to building design may not consider the broader sustainability issues of the urban design.[243]

Passive building design and heat resistance

Appropriate architectural design can assist in establishing comfortable indoor environments without air conditioning. Passive design principles that contribute to the heat resistance of both new and existing building stock typically include shading, thermal mass, insulation, ventilation and spatial planning:[244]

- Shading allows the reduction of building surface temperatures and reduces direct and indirect solar access. Shading can take the form of vegetative shading external to a building and shading integrated into the building design including eaves, overhangs, awnings and verandas.
- Higher thermal mass of buildings (concrete, stone, earth walls and/or heavy weight floors) delay and reduce the impact of external temperature fluctuations. However, in considering heatwave events, the ultimate store of heat in the thermal mass will take longer to dissipate.
- Insulation is a barrier to heat flow and supports the use of more lightweight construction materials. It most commonly comes in bulk (e.g. wool or fibreglass) or reflective form (reflective foil laminates). Insulation is a common barrier between the roof and ceiling to minimise solar heat transfer into a building. External walls may also use insulating materials to minimise heat transfer.
- Ventilation (intentional airflow) is a key requirement for the maintenance of air quality within individual buildings and in consideration of the broader urban design of cities. Cross ventilation of buildings and the ability to (manually) ventilate via window openings is critical for the establishment of heat resistant buildings.
- Spatial planning can refer to the site orientation of a building on a lot, in addition to the internal layout of rooms and corridors. Spatial planning for heat resistance is equally important at the neighbourhood urban design and regional scale to ensure appropriate responses to local geographical and climatic contexts.

Further building design considerations for enhanced heat resistance include:

- Limiting the number of windows on the western (afternoon sun) side of the building, and careful window design and orientation more generally.[245]
- The encouragement of window tinting and double glazing where appropriate.[246]
- A thin building design may provide better cross ventilation[247] while an increase in the size of living space can also provide better ventilation.[248]
- A lighter coloured roof (such as white) to reduce heat absorption.[249]
- The provision of surfaces and building materials that reduce heat retention such as reflective and lighter coloured surfaces on roadways and walkways.[250]
- Building design that allows occupants to control their internal environment using manual systems such as opening windows.[251]
- Education and training for (commercial) building occupants on how to operate the building to ensure optimised normal performance, not just during heatwave events.[252]

Urban planning and urban design

City design can play an important role in reducing urban heating, establishing heat resistance and therein mitigating the impact of heat events. QDesign – developed by the Office of the Queensland Government Architect to improve the quality and standard of built form in Queensland – contains urban design principals including consideration of climate responsive design to manage temperature extremes and urban heat island effect for buildings, streets and spaces. QDesign strategies for climate responsive design that incorporate direct heatwave mitigation measures are:

- take advantage of the local climate and adopt passive design strategies
- reduce the extremes of temperature by using appropriate design and architectural features, as well as landscape elements, to reduce extremes of temperature and urban heat island effect
- use moveable elements to allow manual temperature control and shading
- use appropriate vegetation to provide shade and shelter for pedestrians and cyclists.[253]

Further consideration of the factors influencing preparedness for, and mitigation of, heatwaves can enable clearer integration of stakeholder requirements and increase their potential to contribute to the design and development of heat resistant communities.

When considering heatwaves from a broader urban risk management perspective, two control structures may be recognised:

1. Systems development – preparation, planning and development of the urban environment (normal performance)
2. System operations – response and recovery structures (during and following a heatwave).

In practice, the response and recovery side of urban risk management is understood, generally with well-established notifications, roles and responsibilities, training, and management of heatwave events between the hierarchy of stakeholders. However, the planning and development of heat resistant urban form is generally more fragmented. Accordingly, greater cooperation and coordination between all levels of government, industry and the community to plan and establish context sensitive, sustainable and safe human settlements is required.[254]

Planning with climate data

In most cases, planning and designing buildings according to climatological rules does not significantly increase building costs, but it does improve the quality of life and offer energy and associated cost savings.

The use of urban climate tools such as aerial infrared remote sensing, meteorological measurements, digital orographic models and maps of the air emission can be useful in urban planning by providing thermal maps of the ground, maps of air temperature, air humidity, wind velocity and thermal comfort, and climatic analysis maps.[255]

Such approaches to planning make it possible to assemble and present a range of context sensitive climatic data for community locations and offer residents, workers and local communities insight into local heat resistance. This data may then be presented in strategic planning documents in much the same way as flooding and bushfire vulnerabilities are mapped and published.

Key considerations:

- Data improves awareness of urban climate, cities' temperature trends and future climate. It permits the consideration of heatwave risks in building design, urban planning and development approval processes as well as associated urban landscaping and water policies.[256]
- Data provides planners and councils with the statutory tools to influence development and incorporate climate relevant building regulations in the planning process[257] such as planning scheme requirements that promote cooler homes.[258]
- Non-climatic factors and data, such as technological innovations, motorised transport, behavioural aspects and cultural trends also must be considered in the planning for heat resistant communities.
- The Planning Institute of Australia's Disaster Resilience Education Implementation Plan provides an exemplar of education and awareness focussed on creating disaster resilient communities. The plan is intended as whole of life education, with emphasis on educating primary school children through to ongoing professional development for built environment professionals. Education and awareness that focuses on building heatwave resilience within communities may further improve outcomes.[259]
- A complex range of stakeholders requires a greater awareness of the design, delivery and management of heat resistant built and natural communities. These include: urban planners, engineers, architects, building designers, landscape architects, developers, builders, environmental managers, surveyors, land managers and lawyers.[260]
- Further, opportunity exists for cumulative action via improved communication among all stakeholders.[261]

- Multiple existing schemes and strategies do not have heat resistance and reduction as their principal purpose but can assist in doing so. This includes:
  - Green roofs promoted with the intention of water retention and urban biodiversity also help to reduce the impacts of heatwaves.[262]
  - 'Know your neighbour' campaigns implemented to promote a greater sense of community, can promote a buddy system during a heatwave and reduce heat stress risk for vulnerable socially isolated groups.[263]
  - Active transport initiatives remove cars from the road, reducing anthropogenic heat, while an active lifestyle can help residents to maintain high natural levels of heat acclimatisation.[264]
  - Tree planting, revegetation and urban agriculture initiatives can support the development of heat resistance.

Principles of good urban design

With rapid growth across many of the State's cities and towns, it is important to ensure that the quality of what is being delivered creates an urban environment that is well made, improves the quality of life for all and is distinctly Queensland. The nine QDesign priority principles,[265] along with other good urban design principles, can offer significant contributions to the effective mitigation of heatwave impacts and improve general wellbeing (Figure II). Some examples include:

- Creating a walkable network of streets and public spaces to promote active transport, improving health and acclimatisation to warmer temperatures.
- Social connectedness between individuals and communities is important. Creating inclusive communities can assist in developing social connections and promote a 'check on your neighbour' culture, reducing the risk for those otherwise socially isolated.[266]
- Applying water sensitive urban design measures can help to deliver improved biodiversity, landscape amenity and recreational facilities.
- Public drinking fountains, well-lit parks and public spaces can allow people to cool down safely in the evenings.[267]
- Prioritising climate responsive design features for functional public spaces such as:
  - bus stops/shelters
  - public exercise areas
  - west facing pedestrian areas around schools
  - main intersections
  - car parks
  - footpaths, verges, roads, roundabouts (road reserves).[268]
- The Office of the Queensland Government Architect will be releasing the QCompanion, a supplementary design resource to QDesign to provide ideas and techniques for translation of the nine priority design principles.
- Heatwaves also significantly affect flora and fauna, with many species susceptible to extreme heat conditions. Appropriately designed urban landscapes may provide habitat and protection for urban dwelling native species of flora and fauna.

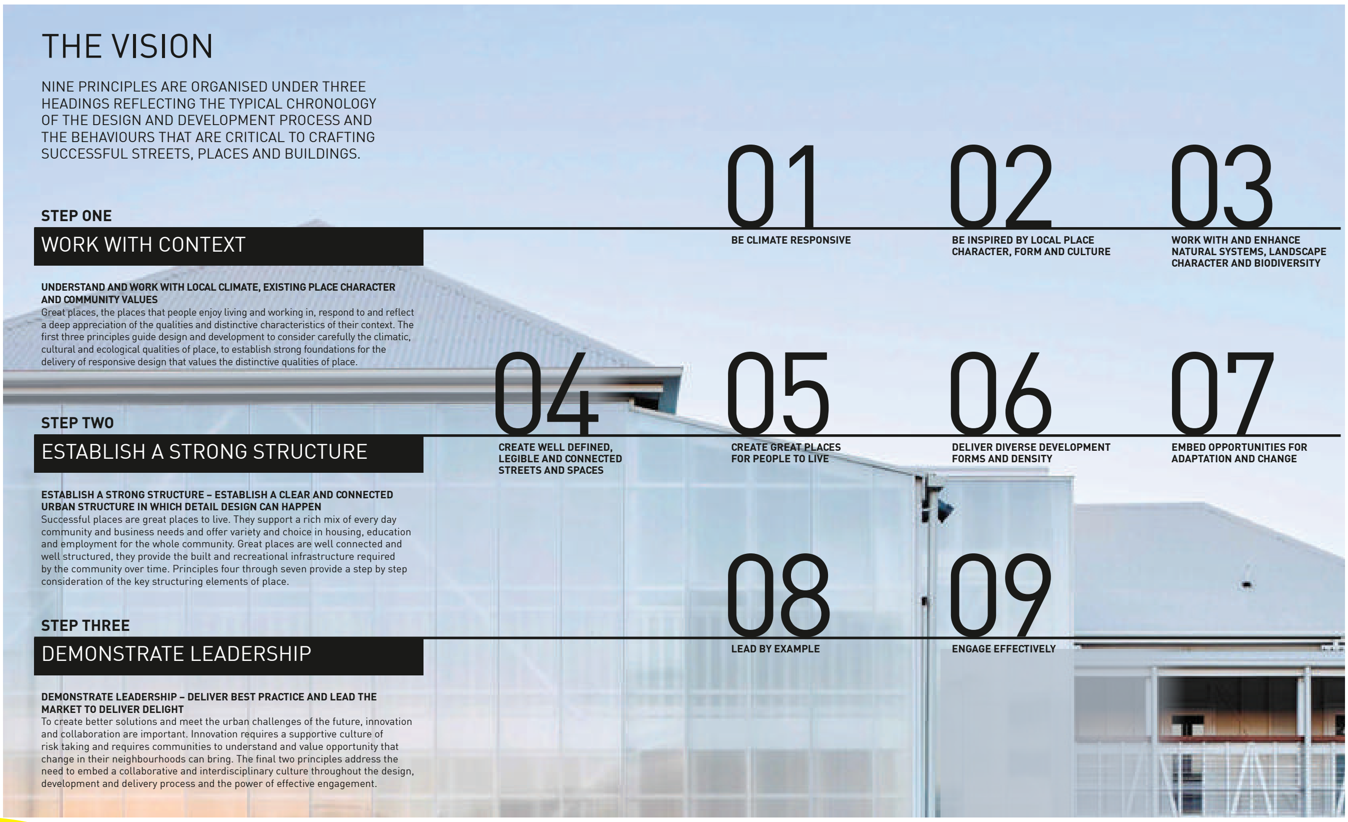


Figure II: The nine QDesign principles. Source: Office of the Queensland Government Architect

Conclusion

Cumulative influences can exacerbate the impact of heatwaves and, in the same regard, the cumulative urban design and urban development responses can assist in the mitigation of these impacts.

Climate and context sensitive building design and urban development is required. This design rationale affords benefits in day-to-day living under average and anticipated conditions, yet also performs to assist in the active mitigation of extreme weather events including heatwave.

Issues of passive design and, more specifically sub-tropical design, are currently overlooked in the broader context of urban development in Queensland. While a reliance on active ventilation and cooling offer the ability to maximise current urban footprints, it presents as unsustainable and short sighted in the face of current climate crises.

The current urban development targets of 60 per cent infill[269] may offer some challenges for the mitigation of the urban heat island effect. Such development will require careful consideration of both urban design and the range of transport, power and social infrastructure capacities and redundancies.

Engineering offers only a partial solution to heatwave mitigation: broader societal and behavioural changes are required within our built environments.

Authored by Centre for Human Factors and Sociotechnical Systems, University of Sunshine Coast, and Hazard and Risk Unit, Queensland Fire and Emergency Services

Appendix E: Organisations participating in the State Heatwave Risk Assessment development process

- AgForce Queensland
- Aurizon
- Australian Defence Force
- Australian Red Cross
- Blackall-Tambo Regional Council
- Balonne Shire Council
- Banana Shire Council
- Barcaldine Regional Council
- Barcoo Shire Council
- Brisbane City Council
- Bundaberg Regional Council
- Bureau of Meteorology
- Cairns and Hinterland Hospital and Health Service
- Cairns Regional Council
- Central Queensland Hospital and Health Service
- Central West Hospital and Health Service
- Charters Towers Regional Council
- City of Gold Coast
- Council on the Ageing (COTA) Queensland
- Darling Downs Hospital and Health Service
- Department of Agriculture and Fisheries
- Department of Communities, Disability Services and Seniors
- Department of Education
- Department of Environment and Science
- Department of Housing and Public Works
- Department of Innovation, Tourism Industry Development and the Commonwealth Games
- Department of Natural Resources, Mines and Energy
- Department of State Development, Manufacturing, Infrastructure and Planning
- Department of Transport and Main Roads
- Douglas Shire Council
- Energy Queensland Group
- Fraser Coast Regional Council
- Geoscience Australia
- Gladstone Regional Council
- Gold Coast Hospital and Health Service
- Great Barrier Reef Marine Park Authority
- Griffith University
- Gympie Regional Council
- Inspector-General Emergency Management
- James Cook University
- Livingstone Shire Council
- Local Government Association of Queensland
- Logan City Council
- Longreach Regional Council
- Mackay Regional Council
- Mackay Hospital and Health Service
- Mareeba Shire Council
- Maranoa Regional Council
- Metro North Hospital and Health Service
- Metro South Hospital and Health Service
- Moreton Bay Regional Council
- Murweh Shire Council
- National Climate Change Adaptation Facility
- National Broadband Network
- Natural Resources Management (NRM) Regions Queensland
- North West Hospital and Health Service
- Noosa Shire Council
- Optus
- Paroo Shire Council
- Powerlink
- Queensland Ambulance Service
- Queensland Council of Social Services
- Queensland Farmers' Federation
- Queensland Fire and Emergency Services
- Queensland Government Insurance Fund
- Queensland Health
- Queensland Parks and Wildlife Service
- Queensland Police Service
- Queensland Rail
- Queensland Reconstruction Authority
- Queensland Treasury
- Queensland University of Technology
- Queensland Urban Utilities
- Seqwater
- South West Hospital and Health Service
- Southern Downs Regional Council
- Sunshine Coast Council
- Sunshine Coast Hospital and Health Service
- Sunwater
- Redlands City Council
- Rockhampton City Council
- Royal Society for the Prevention of Cruelty to Animals (RSPCA) Australia
- Tablelands Regional Council
- Telstra
- The Australia Institute
- Torres Strait Island Regional Council
- Townsville Hospital and Health Service
- UnitingCare Queensland
- University of Queensland
- University of the Sunshine Coast
- Volunteering Queensland
- West Moreton Health Service
- Wide Bay Hospital and Health Service
- Winton Shire Council
- Wujal Wujal Aboriginal Shire Council

Appendix F: High resolution heatwave projections for nine community typologies (the data)

Objective

This analysis aims to support the State heatwave Risk Assessment by providing high resolution heatwave projections for nine community typologies with different socio-economic profiles.

Downscaled Climate Projections

Eleven state-of-the-art climate models were downscaled using dynamic downscaling to produce regional scale simulations (10 km) until the end of the current century using Representative Concentration Pathway 8.5 (see Table 1). Minimum and Maximum daily temperatures were then bias corrected against observations to assess changes in heatwave characteristics in future.

Table 1. Eleven CMIP5 General Circulation Models downscaled over Queensland.

CMIP5 MODEL NAME	MODEL NAME	INSTITUTION NAME(S)	COUNTRY OF ORIGIN
ACCESS1-0	Australian Community Climate and Earth-System Simulator, version 1.0	CSIRO & BoM	Australia
ACCESS1-3	Australian Community Climate and Earth-System Simulator, version 1.3	CSIRO & BoM	Australia
CCSM4	Community Climate System Model, version 4	NCAR	USA
CNRM-CM5	Centre National de Recherches Météorologiques Coupled Global Climate Model, version 5	CNRM-CERFACS	France
CSIRO-Mk3.6	Commonwealth Scientific and Industrial Research Organisation Mark 3.6.0	CSIRO & Qld Govt	Australia
GFDL-CM3	Geophysical Fluid Dynamics Laboratory Climate Model, version 3	GFDL NOAA	USA
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory Earth System Model with Modular Ocean Model, version 4 component	GFDL NOAA	USA
HadGEM2	Hadley Centre Global Environment Model, version 2	Met Office Hadley Centre	UK
MIROC5	Model for Interdisciplinary Research on Climate, version 5	AORI Japan	Japan
MPI-ESM-LR	Max Planck Institute Earth System Model, low resolution	Max Planck Institute	Germany
NorESM1-M	Norwegian Earth System Model, version 1 (intermediate resolution)	Norwegian Climate Centre	Norway

Heatwave Projections

Australia measures and monitors heatwave using the Excess Heat Factor (EHF). The index builds on two concepts, the excess heat and the heat stress. The excess heat is denoted by an unusually high daytime temperature that is not discharged overnight because of high minimum temperature. The heat stress happens when the average temperature is warmer than the recent past and is expressed as a short-term anomaly. In order to represent and quantify heatwave changes we explore a range of different characteristics of heatwaves. The heatwave characteristics are represented by eight indices, seven of them based on the EHF, while one of them (TX40) is calculated directly with maximum daily temperatures (see Table 2).

as a short-term anomaly. In order to represent and quantify heatwave changes we explore a range of different characteristics of heatwaves. The heatwave characteristics are represented by eight indices, seven of them based on the EHF, while one of them (TX40) is calculated directly with maximum daily temperatures (see Table 2).

Table 2. Heatwave characteristics assessed through heatwave indices.

ACRONYM	HEATWAVE INDEX	DEFINITION
HWA	Heatwave amplitude	Amplitude of the hottest day of the hottest heatwave of the year, denoted by the maximum EHF of the heat-wave with highest mean EHF (°C2)
HWAt	Temperature of heatwave amplitude	Average mean temperature (in °C) of the heatwave amplitude as per the above calculation.
HWM	Heatwave magnitude	Average magnitude of all heatwave days across the year, given by the average of all EHF higher than 1 (°C2)
HWMt	Temperature of heatwave magnitude	Average mean temperature (in °C) of the heatwave magnitude as per the above calculation.
HWN	Heatwave number	Number of heatwave events throughout the year (number)
HWF	Heatwave frequency	Number of heatwave days relative to number of days in an year - i.e., (number of heatwave days/365)*100 (%)
HWD	Heatwave duration	Number of days of the longest heatwave of the year (days)
TX40	Number of days with maximum temperature above 40 °C	Number of days in a year with maximum temperature above 40 °C (days)

Regions

Nine community typologies have been selected by QFES. Regions boundaries generally follow Local Government Areas (LGAs). When LGAs were too small to represent regional climate processes, they were grouped with adjacent LGAs with similar climate (see Table 3). Gold Coast City is an exception to this rule as we aimed to represent community with complex urban environment.

Table 3. Selected community typologies to present regionalised high resolution heatwave projections.

	REGION NAME	LOCAL GOVERNMENT AREAS
1	Eastern Gulf of Carpentaria	Mapoon Aboriginal Shire, Napranum Aboriginal Shire, Pormpuraaw Aboriginal Shire, Kowanyama Aboriginal Shire
2	Mount Isa City	Mount Isa City
3	Etheridge Shire	Etheridge Shire
4	Wet Tropics Coast	Douglas Shire, Cairns Regional, Cassowary Coast Regional
5	Longreach Regional	Longreach Regional
6	Mackay Regional	Mackay Regional
7	Central Highland Regional	Central Highland Regional
8	Maranoa Regional	Maranoa Regional
9	Gold Coast City	Gold Coast City

Guide to interpret results of analysis

Box-Whisker plots

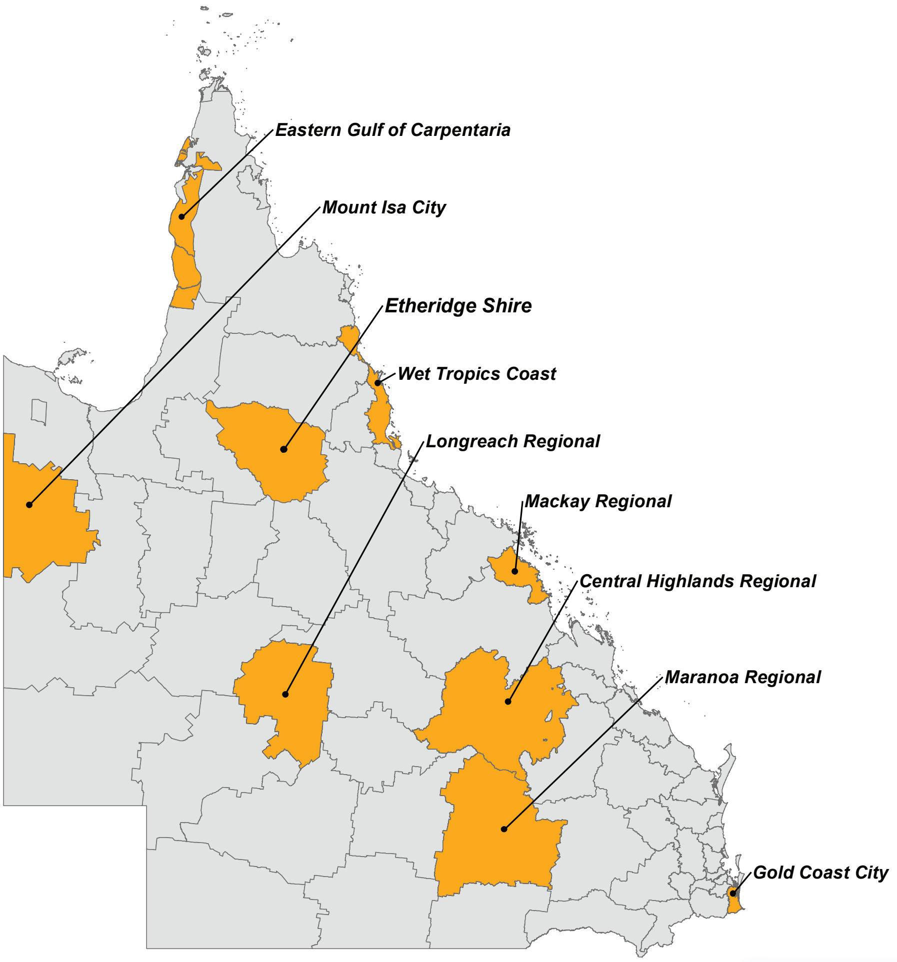
Our first analytical strategy was to assess changes in long-term averages of heatwave characteristics. We used Box-Whisker plots overlayed with jitter plots to illustrate model variability and uncertainty. A multi-part figure is presented for each region comparing long-term averages of eight heatwave indices over time with box-whisker plots. The coloured dots represent individual models as per legend in the bottom of the page. The boxes are bound by the 25th and 75th percentiles of the datasets, whereas the heavy midline displays the median value. The upper and lower "whiskers" represented by the vertical lines are the upper quartile plus 1.5 times the interquartile distance (IQD) and the lower quartile minus 1.5 times the IQD.

Time-series plots

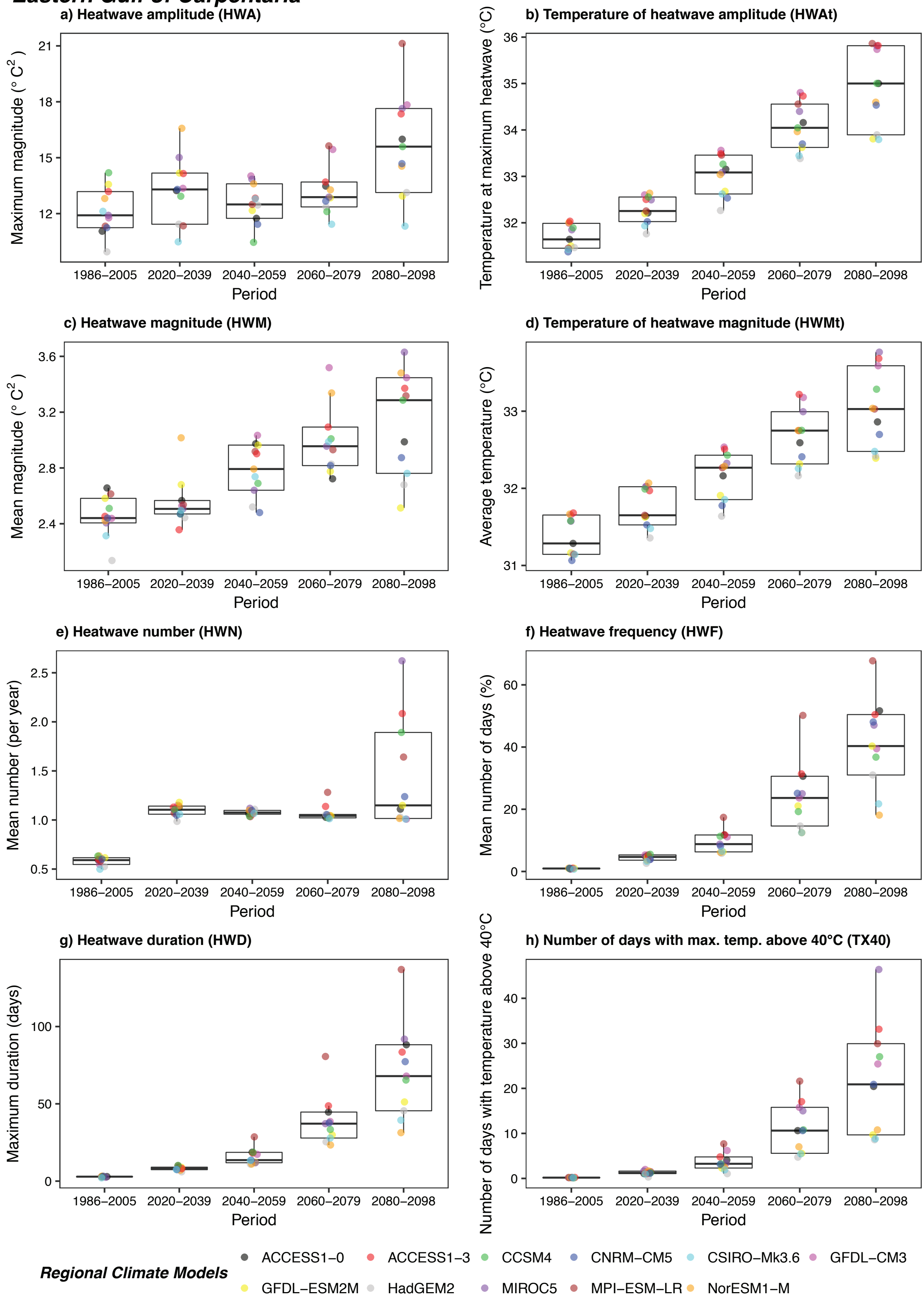
Our second analytical strategy explores the data on annual time-step making use of the high temporal resolution of our modelling framework. We have computed annual averages of heatwave indices – represented in the plots with red lines. In addition, we computed the 15th and 85th percentiles – represented in the plots as lower and upper bounds of grey shaded areas respectively – to illustrate uncertainty. In practical terms, this approach excludes the most optimistic and pessimistic simulation of every single year and provide an uncertainty envelope of regional heatwave characteristics over time.

Authored by the Climate Science Division, Department of Environment and Science.

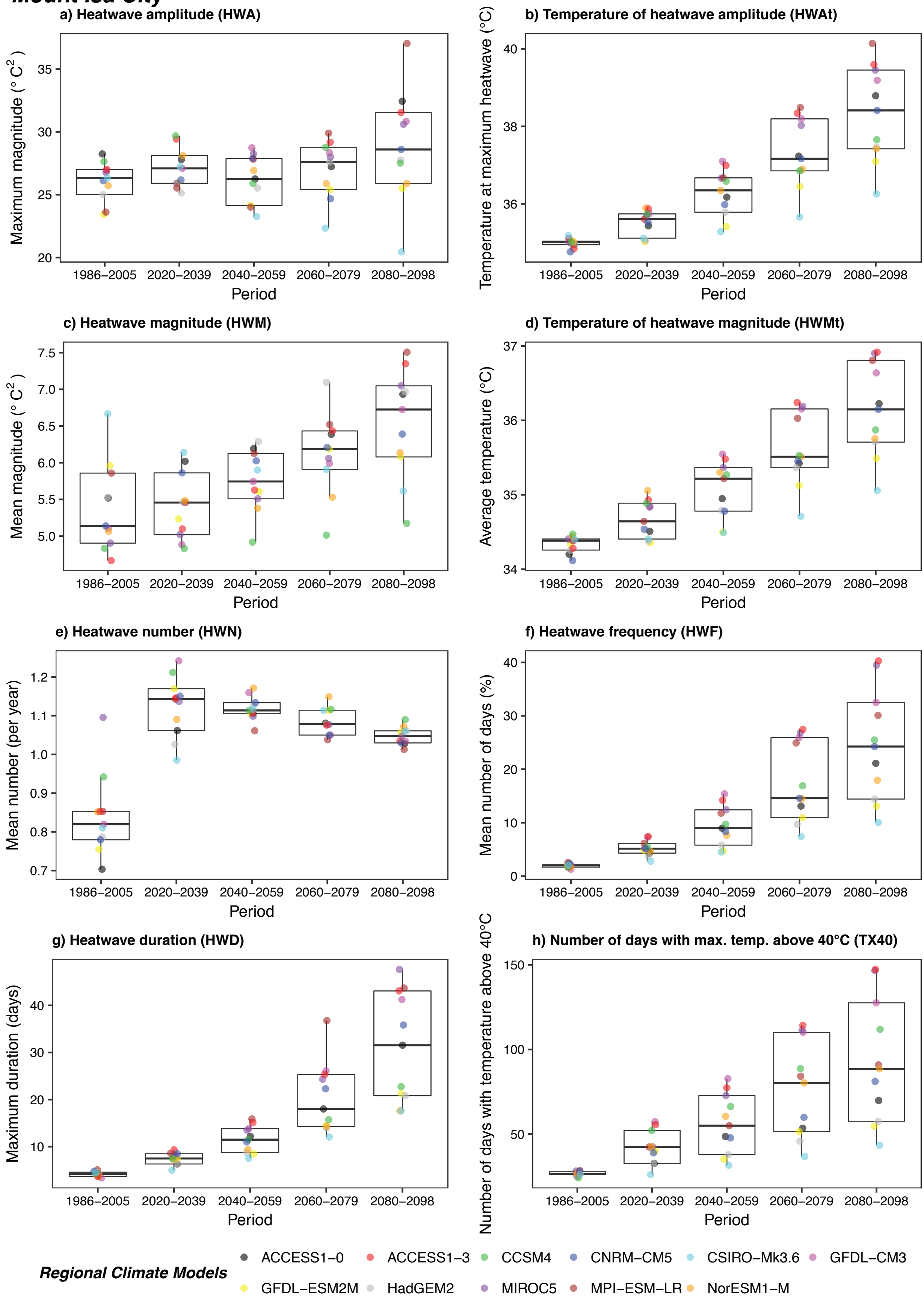
Nine community typologies selected by QFES to present high resolution heatwave projections in the State Heatwave Risk Assessment



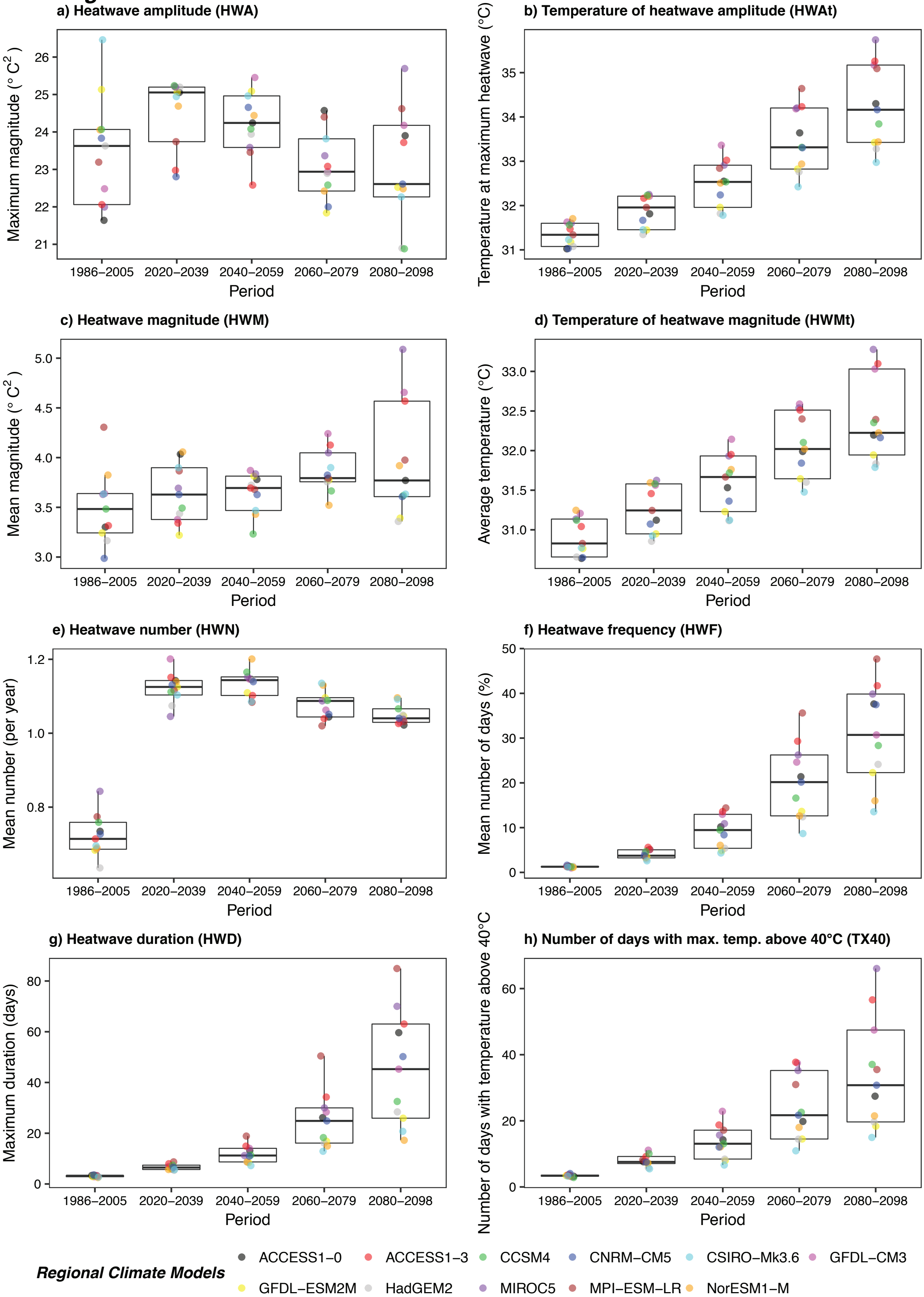
Eastern Gulf of Carpentaria



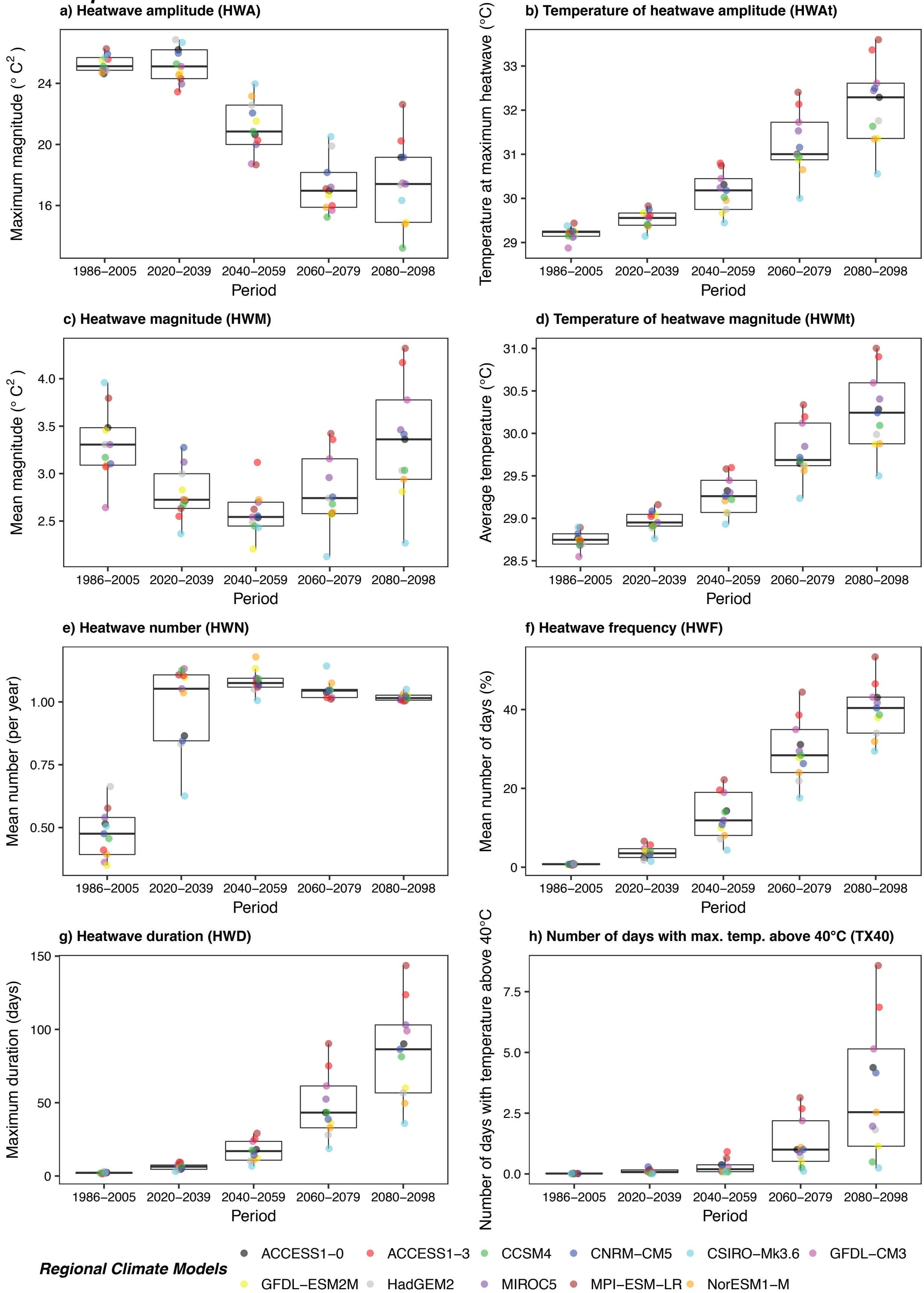
Mount Isa City



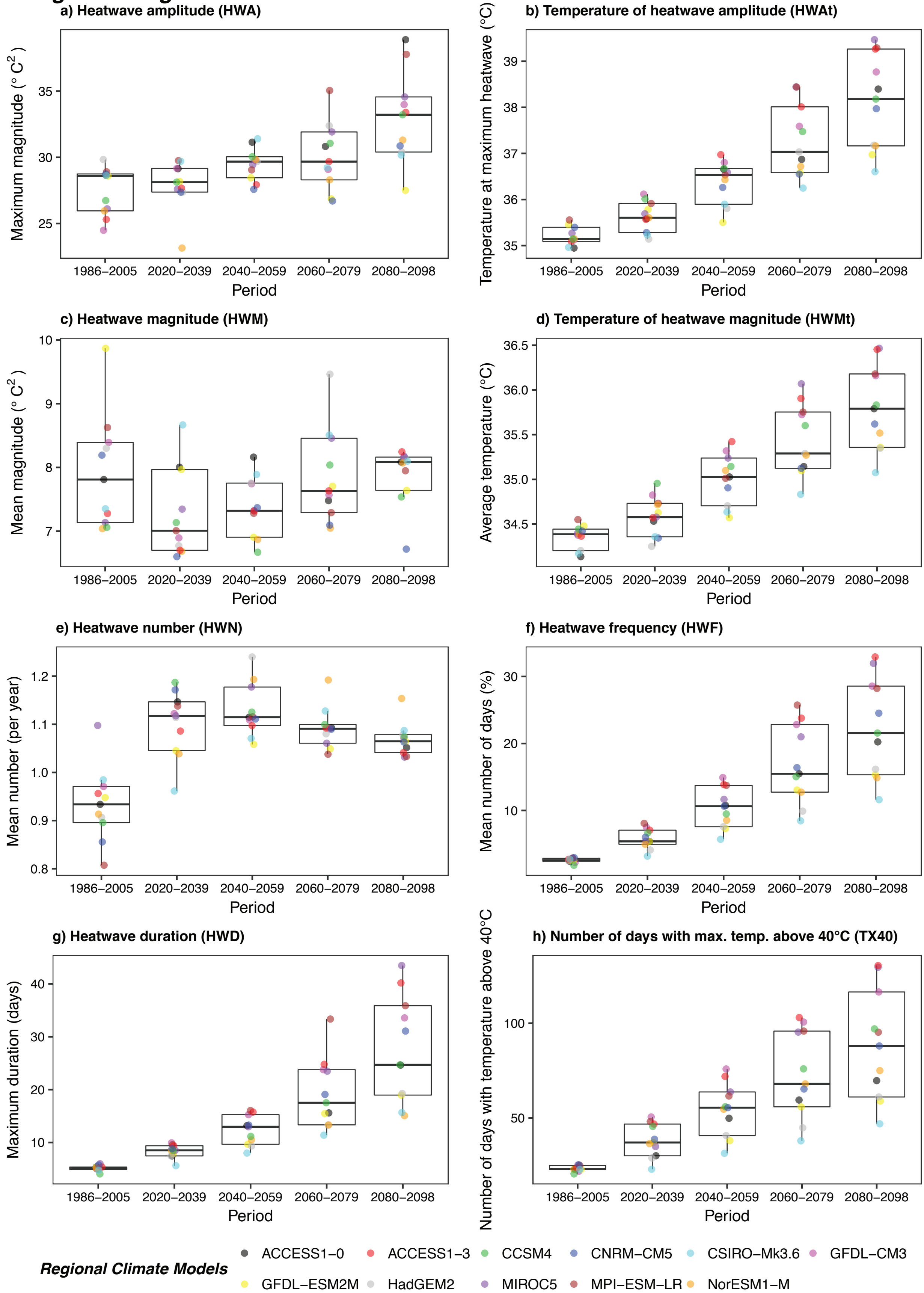
Etheridge Shire



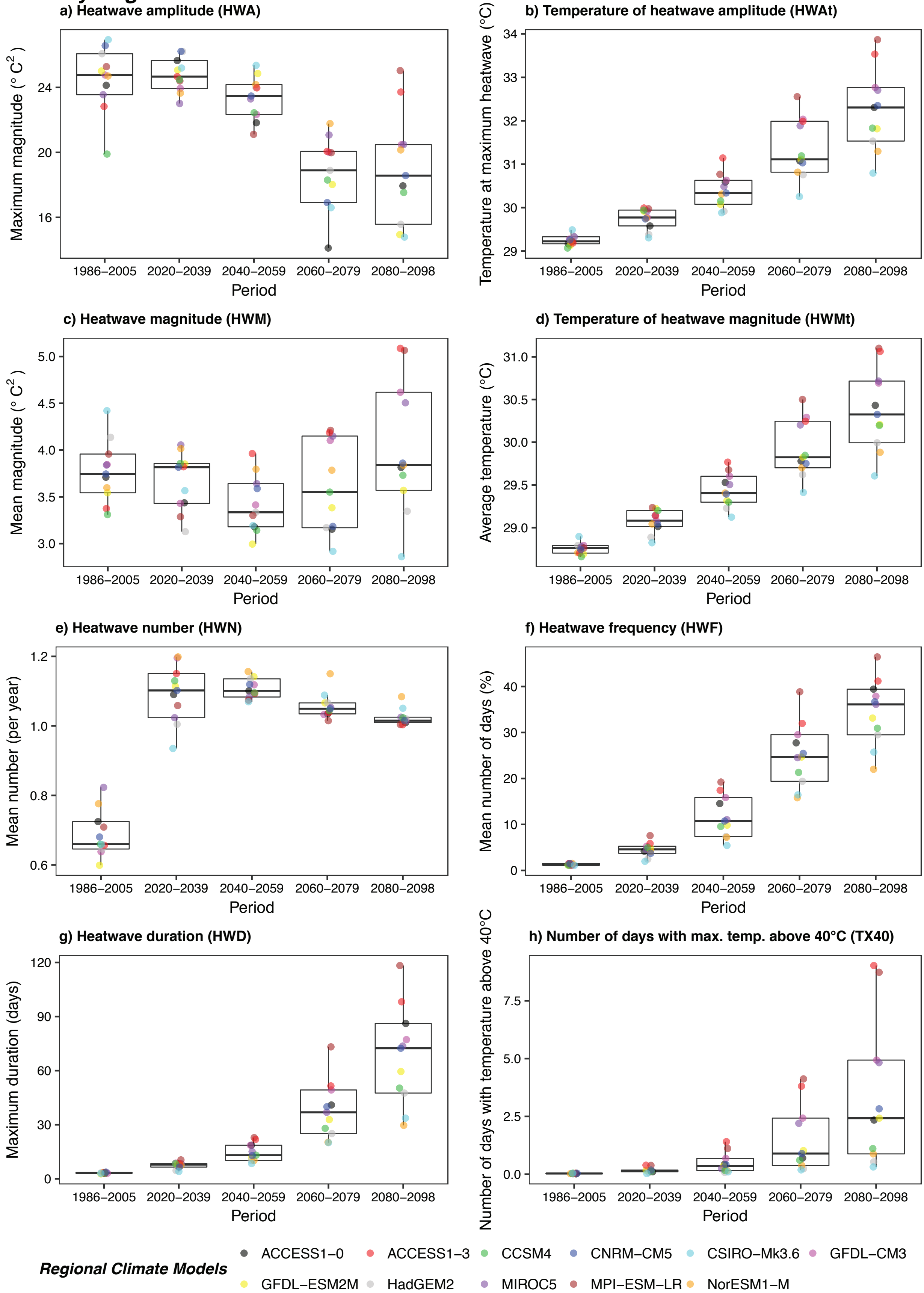
Wet Tropics Coast



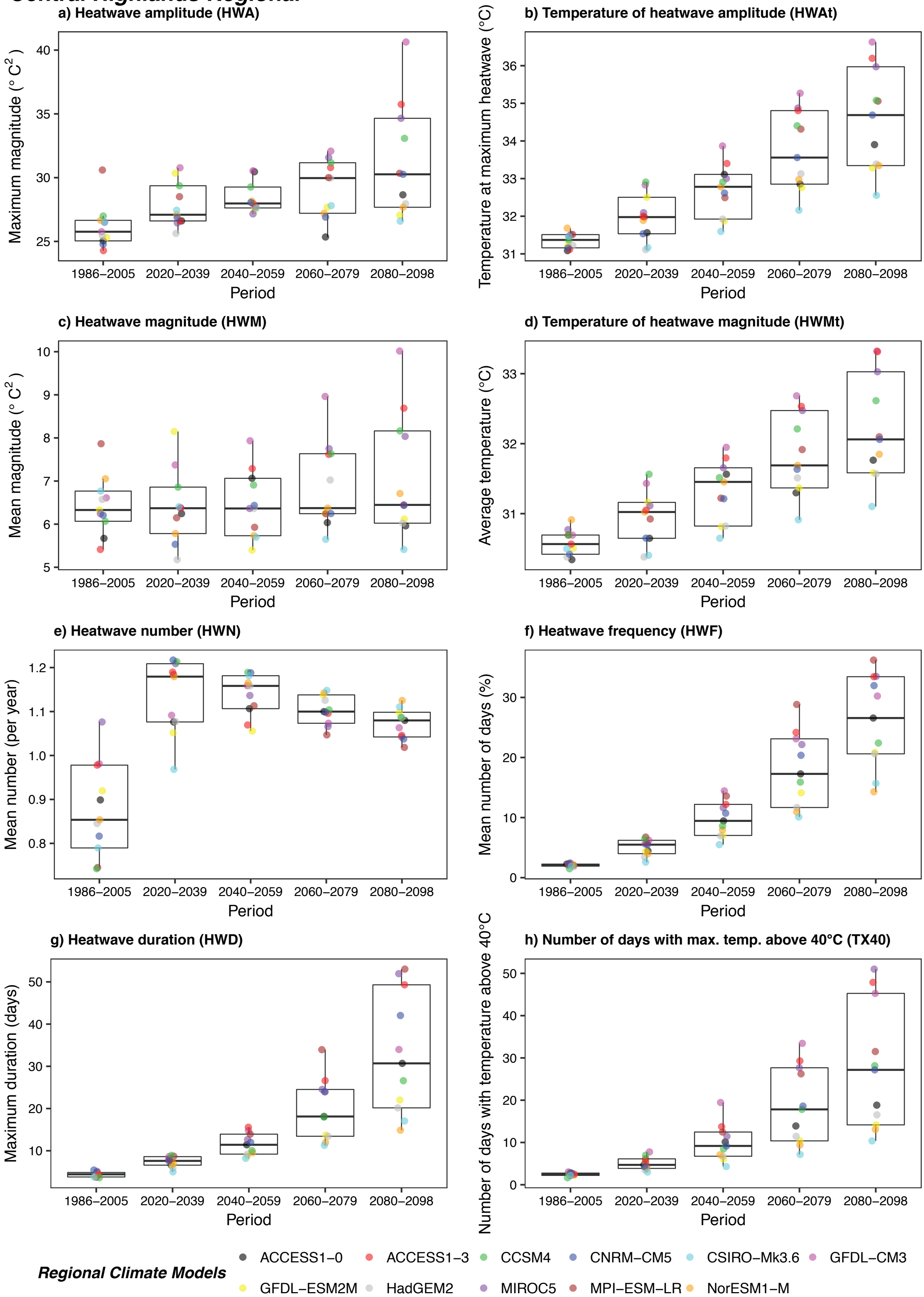
Longreach Regional



Mackay Regional



Central Highlands Regional



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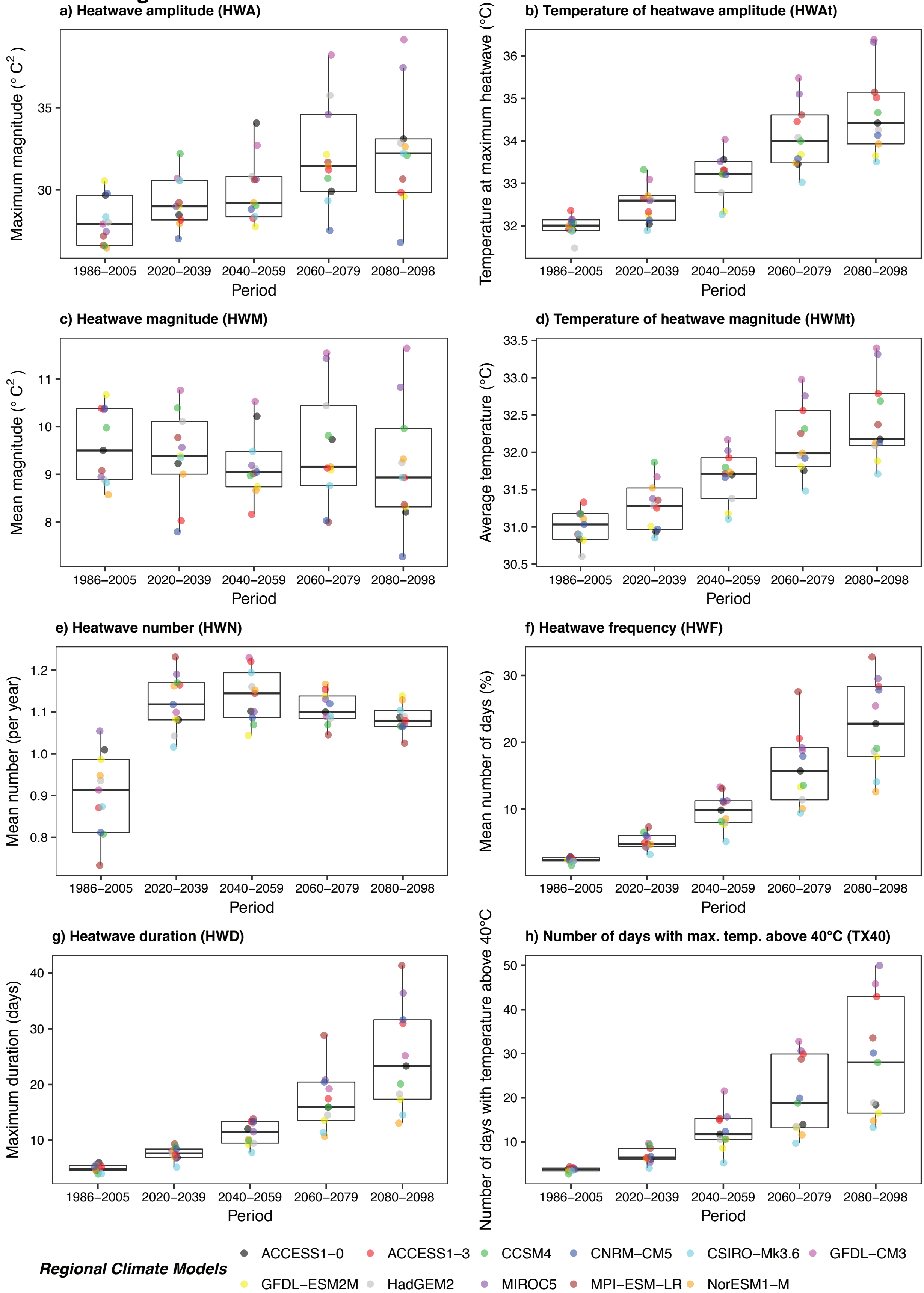
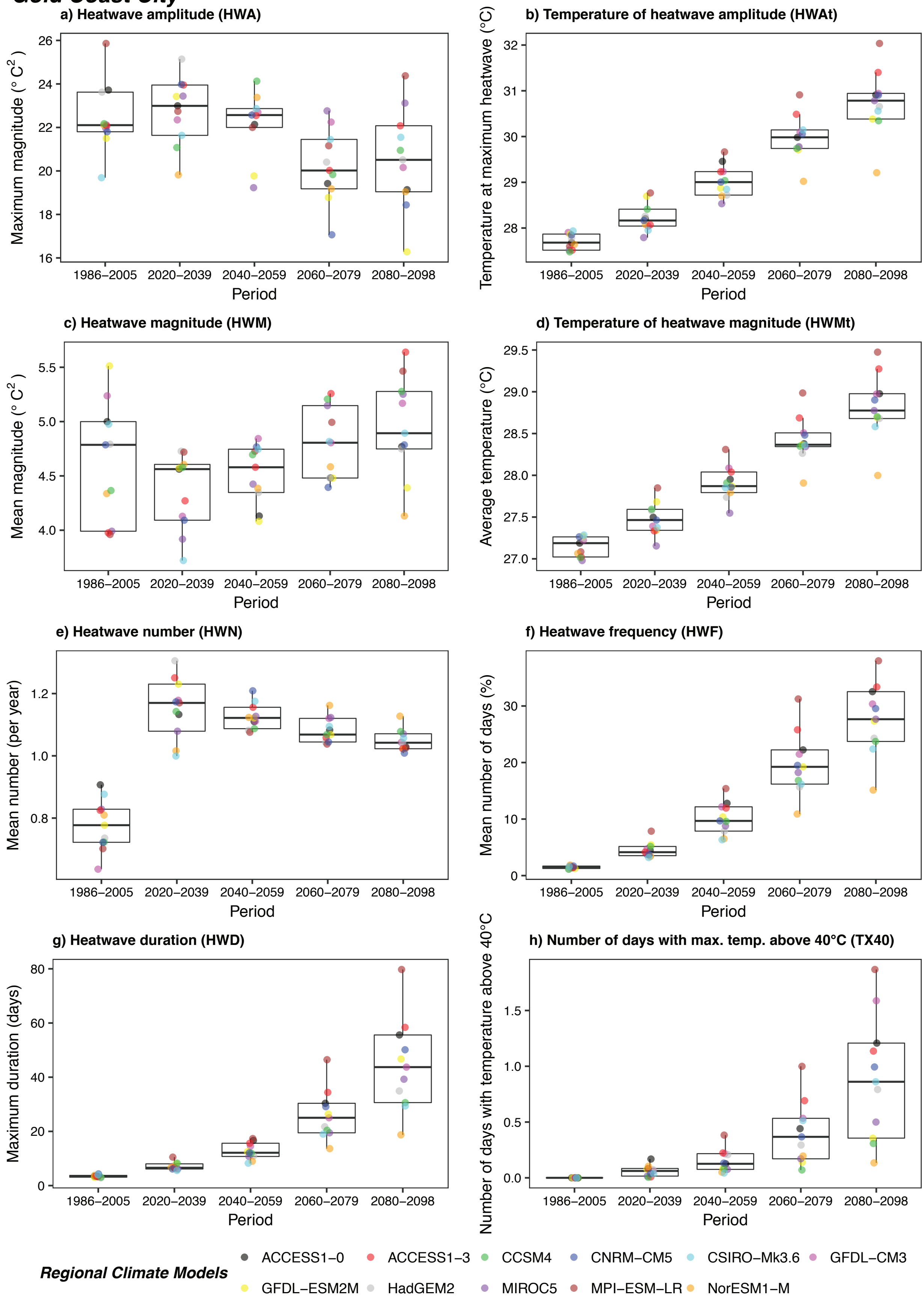


Gold Coast City



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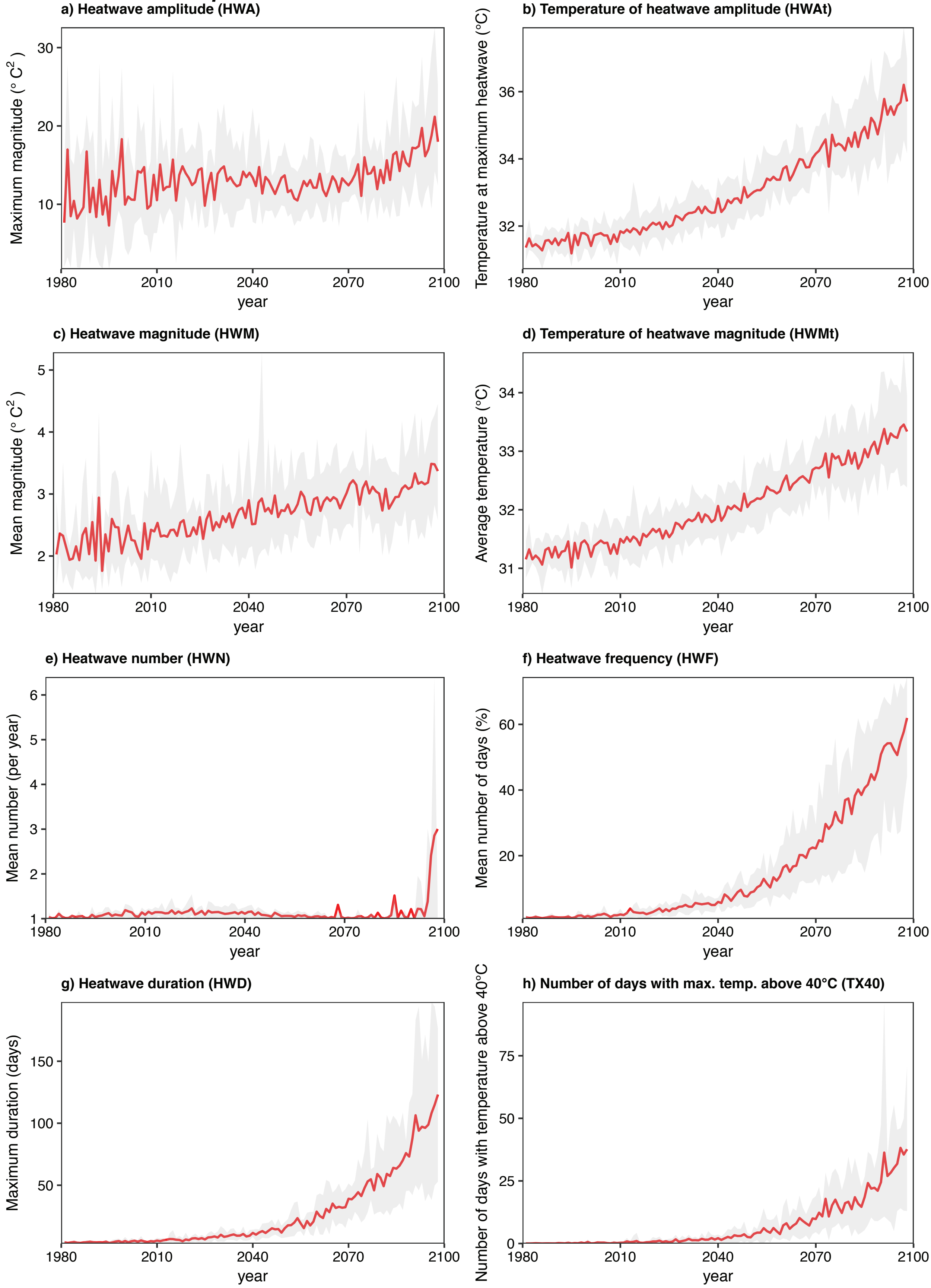

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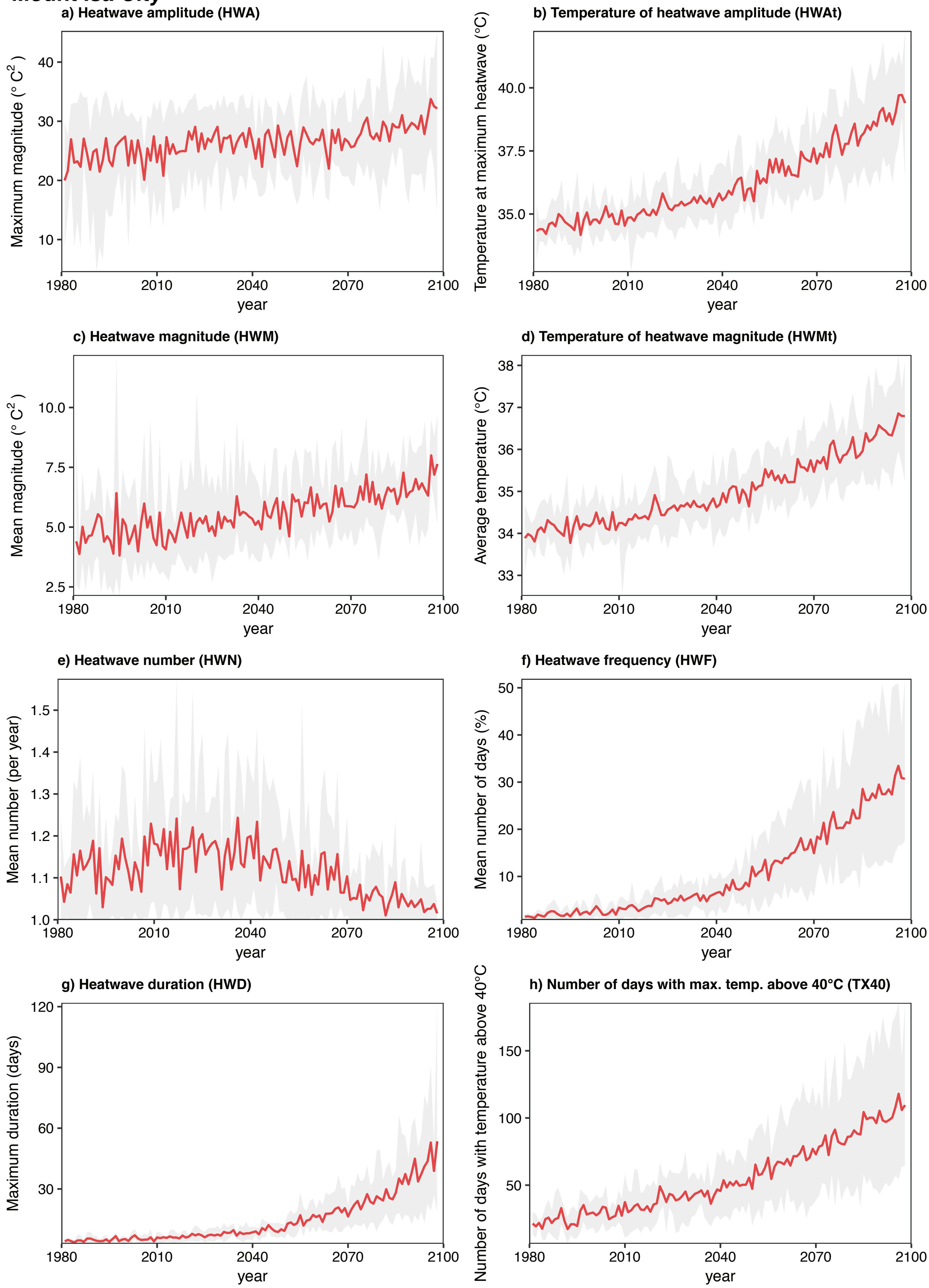

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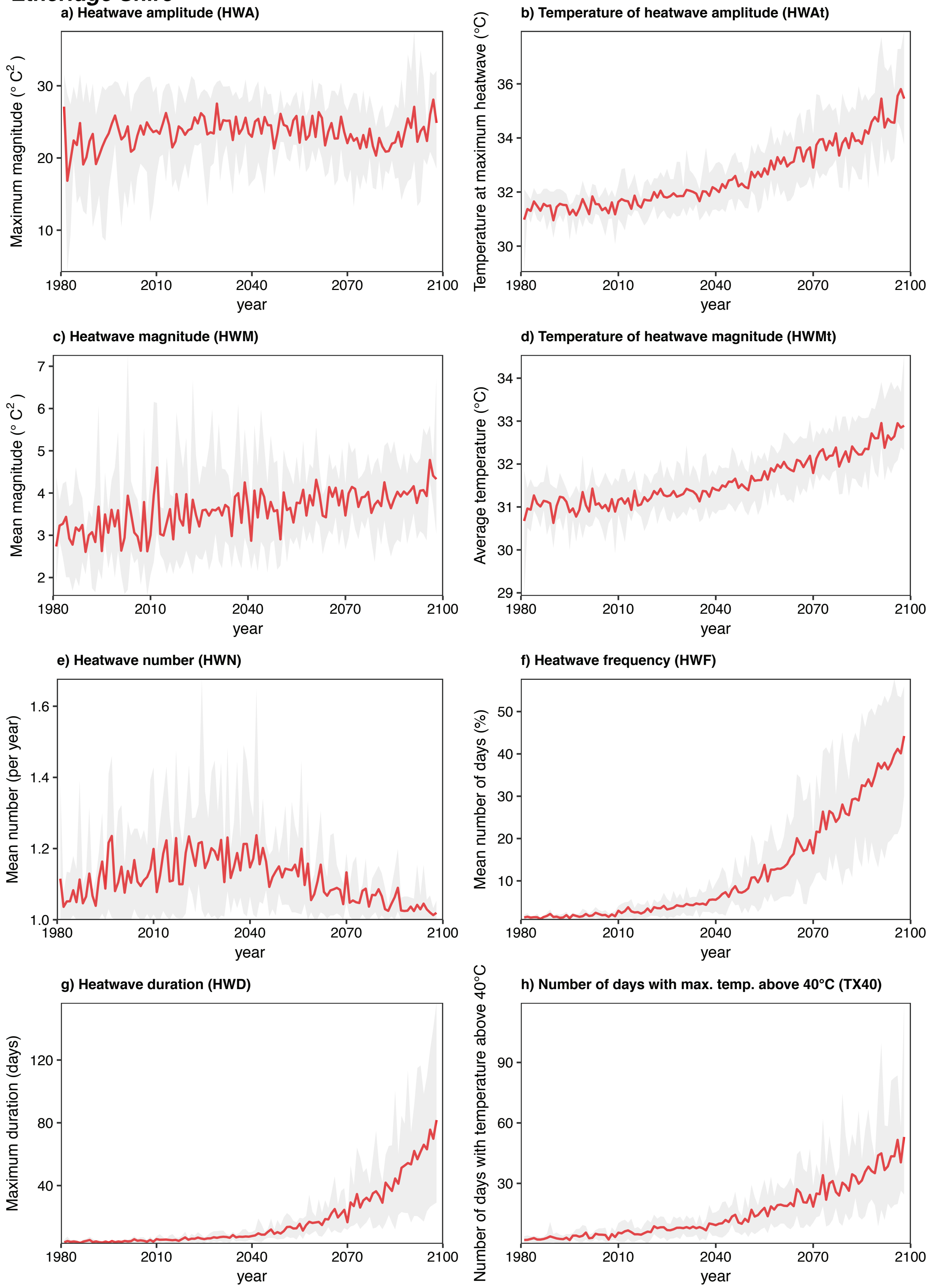

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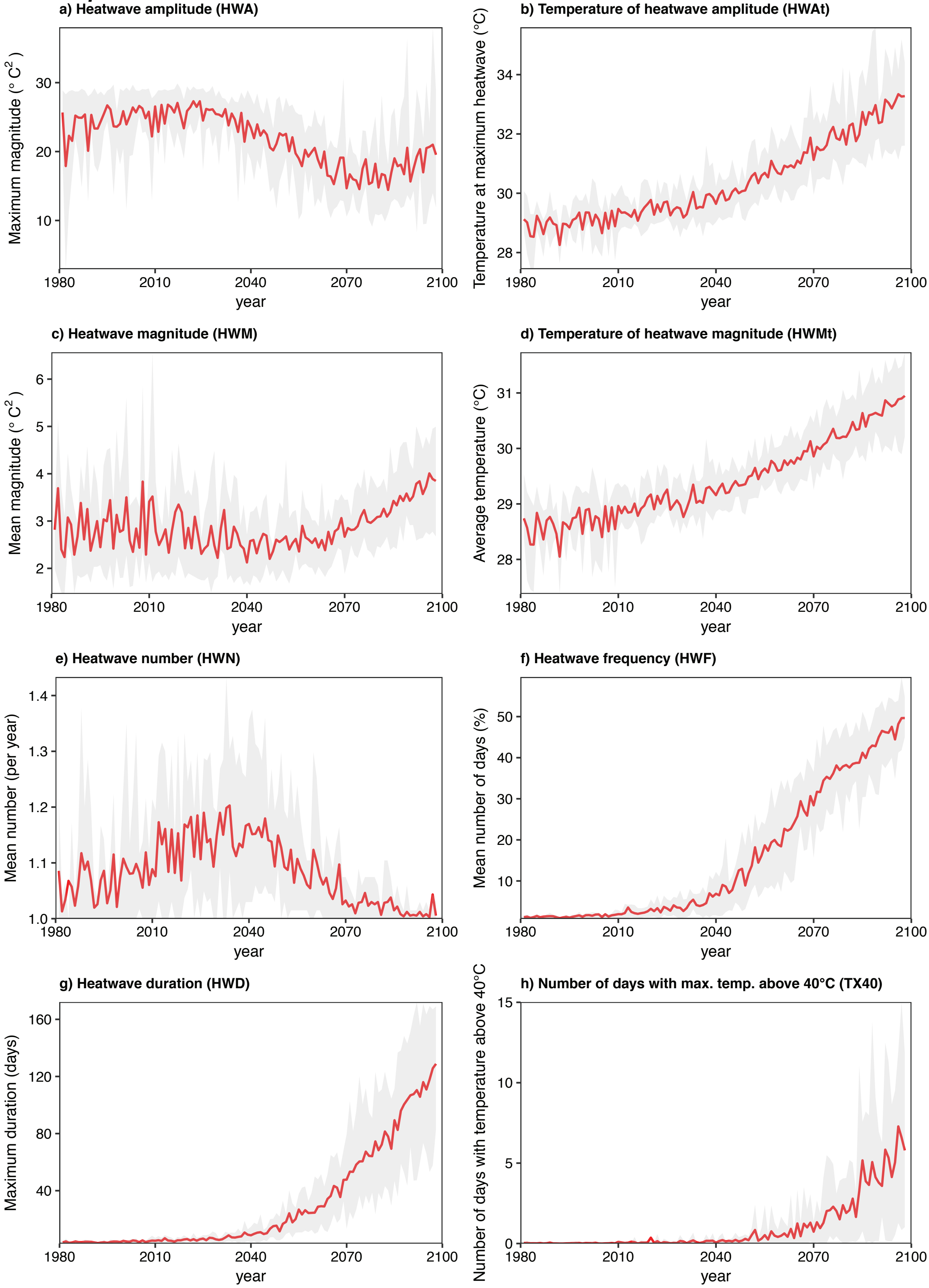

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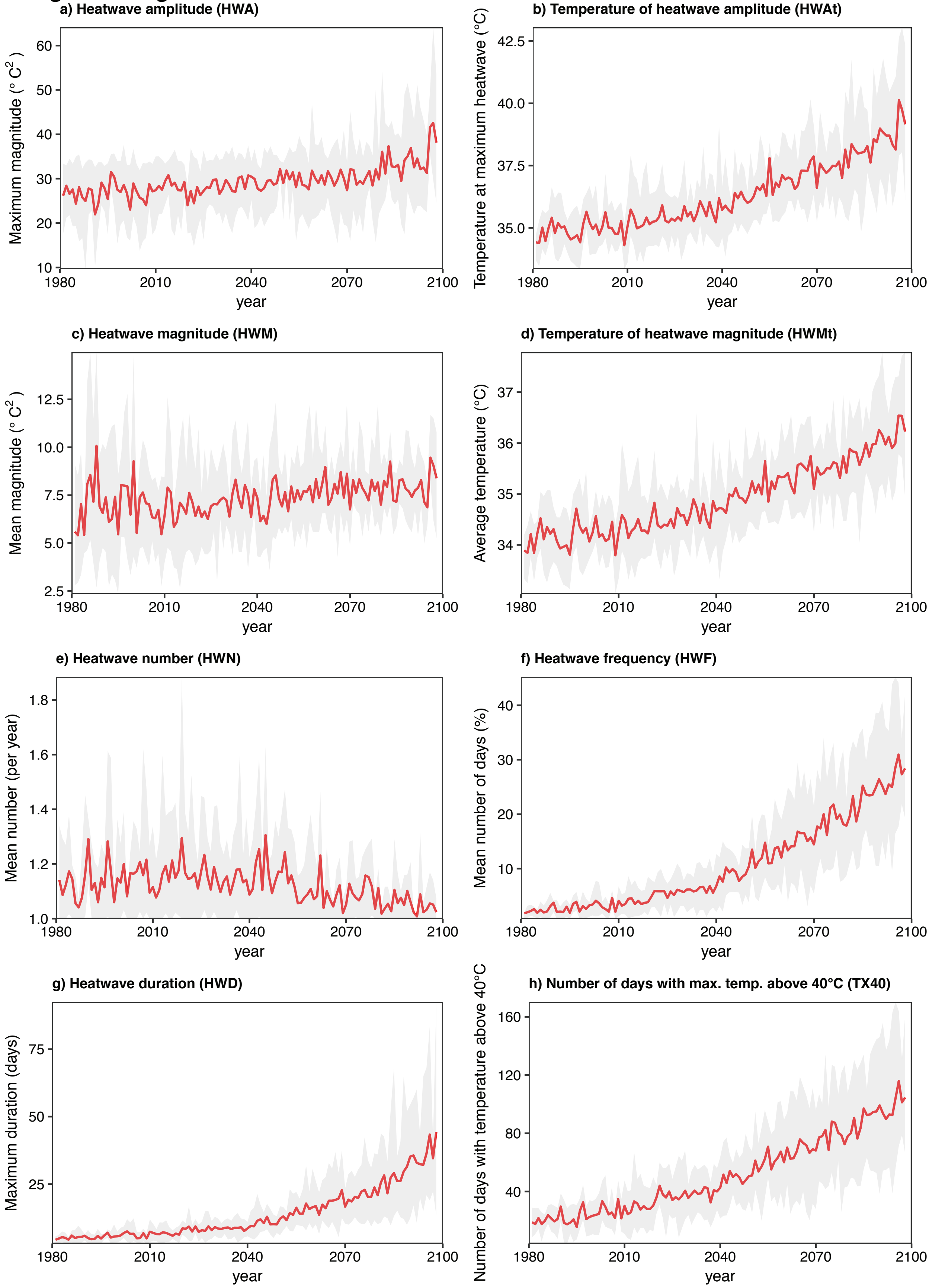

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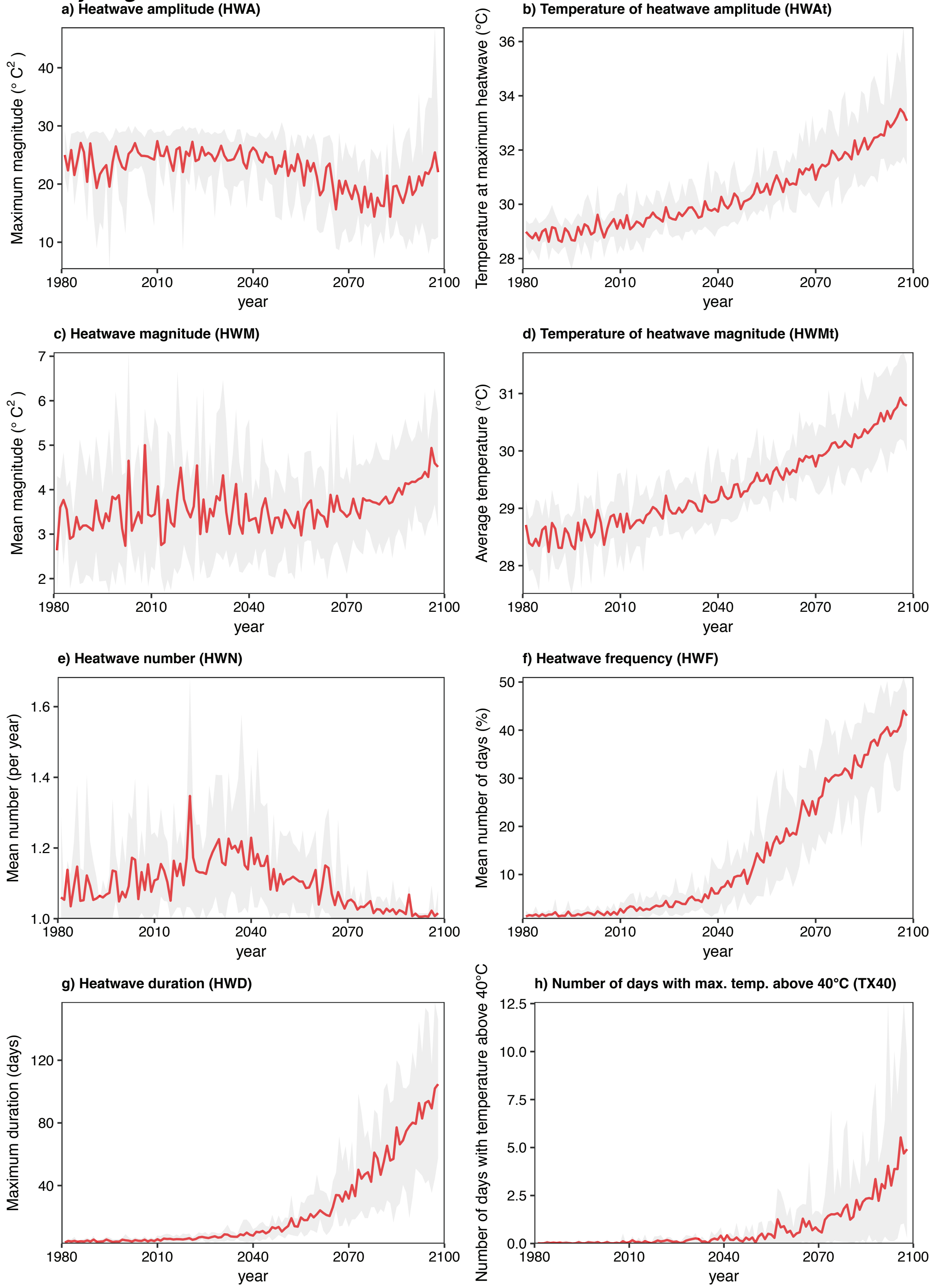
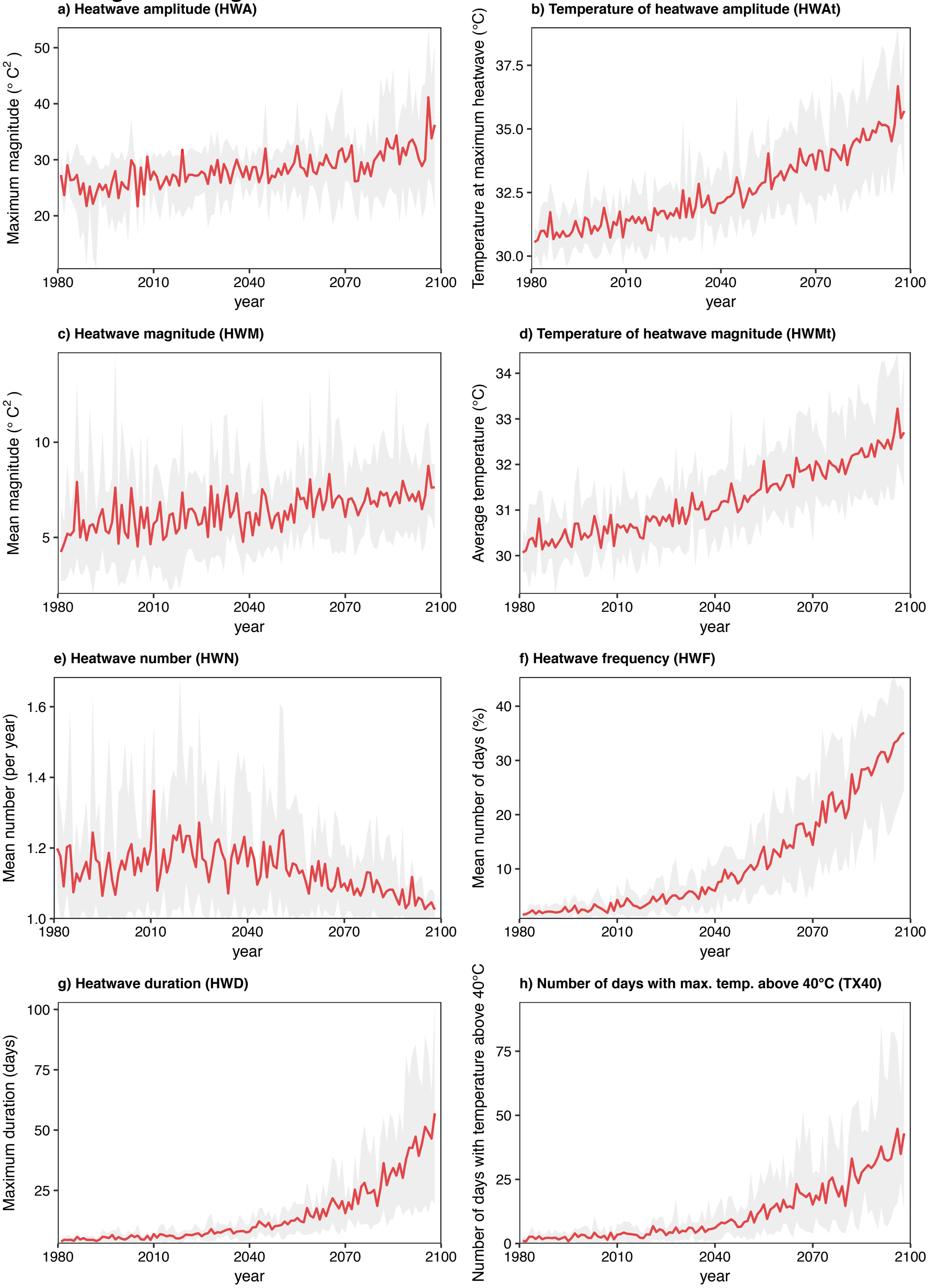


Central Highlands Regional



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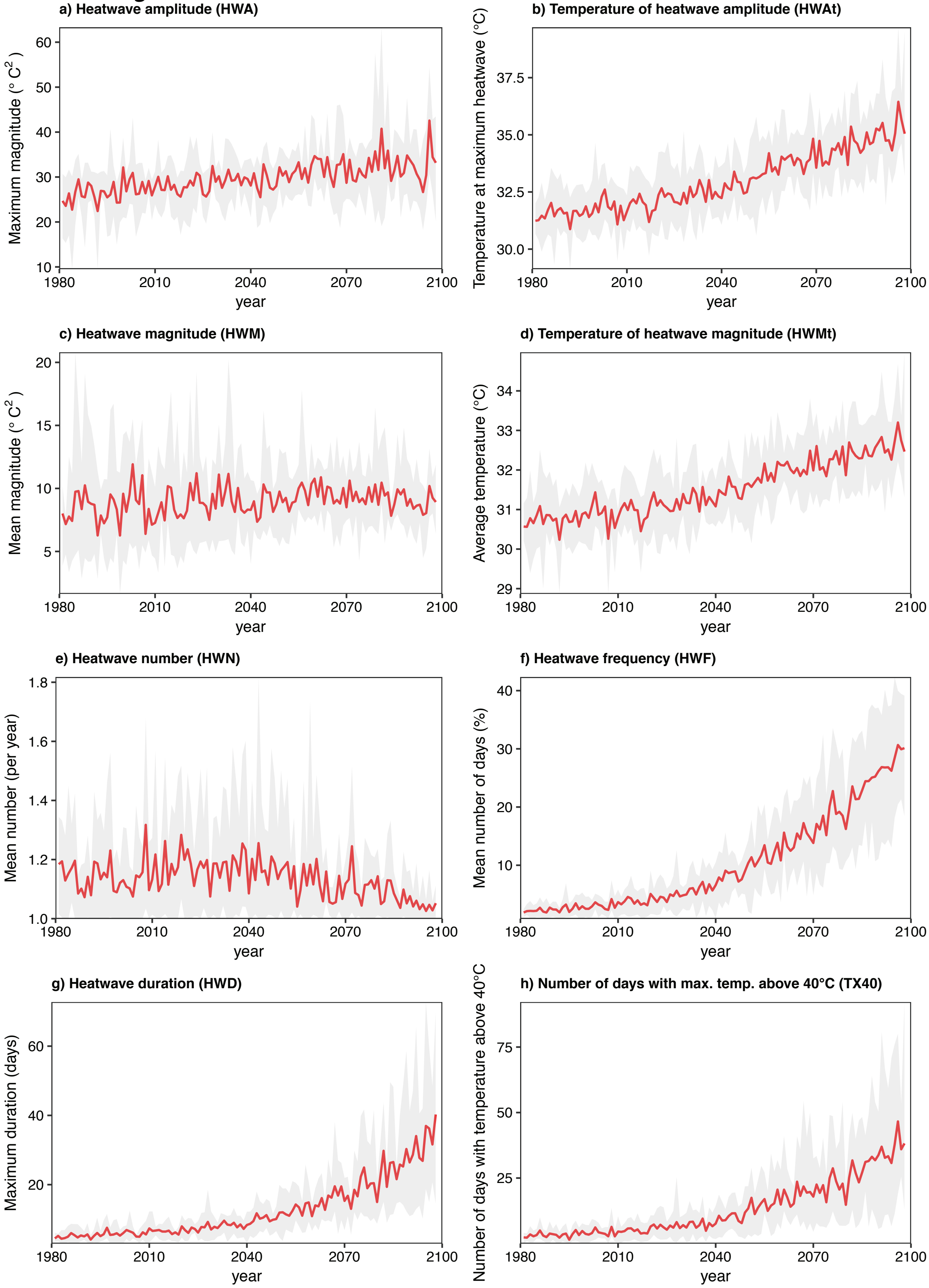

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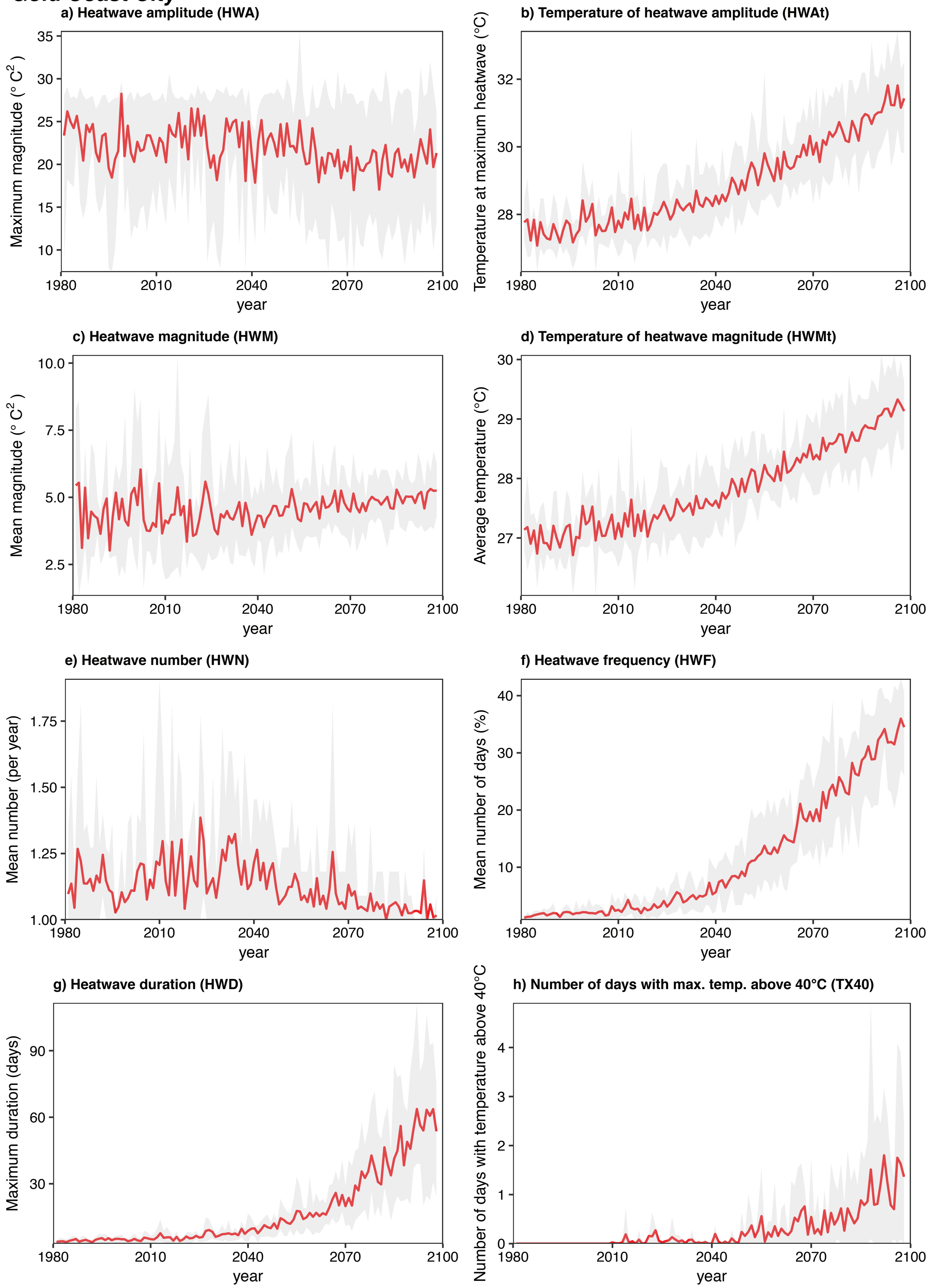

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