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Heatwatch

Extreme heat in the Sunshine Coast

Increasing extreme heat will have profound effects on people, industries and ecosystems in Queensland's Sunshine Coast region. CSIRO and Bureau of Meteorology projections estimate that the average number of days over 35 in the region could increase up to tenfold without strong climate policies from a current average of three to 32 days by 2090. More than half of summer nights are projected to remain above 25 degrees by 2090, a level considered dangerous to human health.

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Travis Hughes
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Summary

The combination of projected rises in extreme heat as a result of global warming and the high levels of humidity in the Sunshine Coast present a serious risk to the health and wellbeing of the region's population.

The Sunshine Coast has historically experienced a relatively pleasant climate with only around two to four days over 35 degrees per year. However, the amount of these extreme heat days could increase nearly tenfold up to a projected 32 days over 35 by 2090.

At temperatures above 35 degrees the human body's ability to cool itself reduces, making it a common benchmark temperature for occupational health and safety experts, academic and government agencies.

Over the last year there were 94 days - concentrated in summer - with a relative humidity of 70% or above and 44 days over 80% or above at 3pm in the Sunshine Coast Combined with 70% humidity, conditions over 35 degrees are considered "dangerous" by government agencies such as the US Government National Oceanic and Atmospheric Administration. Temperatures of 35 degrees combined with 80% humidity is considered "extremely dangerous".

Alarmingly, CSIRO and Bureau of Meteorology (BoM) projections show that unless emissions are decisively reduced, well over half of summer nights could be over 25 degrees by 2090 in the Sunshine Coast from an average of just one summer night over 25 now. Nights where the minimum temperature does not fall below 25 degrees are considered an extreme temperature threshold and can have serious health impacts.

The impacts of more extreme heat are already being seen globally with Europe, Russia, India and Pakistan all experiencing heat waves resulting in thousands of deaths.[1,2]

Increased hot days would reduce productivity in important Queensland industries such as agriculture, construction and tourism. The Sunshine Coast specifically would see its large employment sectors of tourism, construction and services greatly damaged.

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[1] Wang, Horten (2015) *Tackling climate change: the greatest opportunity for health The Lancet Climate Change and Human Health Commission*, The Lancet, https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)60854-6/fulltext

[2] Hass, et al. (2016) *Heat and Humidity in the City: Neighbourhood Heat Index Variability in a Mid-Sized City in the Southeastern United States,* International Journal of Environmental Research and Public Health.

Fortunately, these rises in extreme temperatures are not inevitable. CSIRO projections show that if emissions are reduced, the rises are likely to be far lower. With decisive reduction in emissions, the rise in both hot days and nights could be maintained at close to current levels.

Introduction

As the climate warms, the number of extreme temperature days is increasing across Australia. The Sunshine Coast, although known for its consistent warm weather, has seen the number of extreme temperature days increase slightly in recent years and their frequency is forecast to rise dramatically unless emissions are reduced.

Extreme heat is dangerous for human health, ecosystems and agriculture. At temperatures above 35 degrees, the human body's main cooling mechanism – sweating – is far less effective. Sweating exchanges heat from the body to the atmosphere, but this heat exchange process diminishes significantly beyond 35 degrees and, as a result, body temperature rises. This creates discomfort and a range of health impacts, from mild to severe, and can ultimately be fatal without intervention.[3]

Because of this, many regulators and researchers use 35 degrees as an important threshold for safety, work and climatic conditions. 35 degrees is seen as the "Limit of high temperature tolerance" by the Occupational Health and Safety Representatives of the Victorian Trades Hall Council; academic researchers have pointed to this as a point where substantial productivity is lost. The CSIRO and Bureau of Meteorology publish 35 degree threshold predictions.[4]

Temperature and humidity are often combined into a heat index figure to provide a simple indicator of the body's ability to cool itself. Of a number of indices available, one of the most important is published by the US Government National Oceanic and Atmospheric Administration (NOAA). As shown in the NOAA heat stress chart in Figure 1 below, the combination of temperatures in the low thirties with high humidity are considered "dangerous" to human health.

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[3] Hanna and Tait (2015) *Limitations to thermoregulation and acclimatisation challenges human adaptation to global warming,* Int J Environ Res Public Health, https://academic.oup.com/heapro/article/30/2/239/561863

[4] Victorian Trades Hall Council (2018) *Heat*, http://www.ohsrep.org.au/hazards/workplace-conditions/heat; Singh et al (2015) *Working in Australia's heat: health promotion concerns for health and productivity,* Health Promotion International, https://academic.oup.com/heapro/article/30/2/239/561863; CSIRO and BoM (2015) *Climate change in Australia: Projections for Australia's NRM Regions*, https://www.climatechangeinaustralia.gov.au/en/publications-library/technical-report/

Figure 1. NOAA Heat Stress Index

TEMPERATURE (°C)

RELATIVE HUMIDITY (%)	26.7	27.8	28.9	30	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40	41.1	42.2	43.3
40	26.7	27.2	28.3	29.4	31.1	32.8	34.4	36.1	38.3	40.6	42.8	45.6	48.3	51.1	54.4	57.8
45	26.7	27.8	28.9	30.6	31.7	33.9	35.6	37.8	40	42.8	45.6	48.3	51.1	54.4	58.3	
50	27.2	28.3	29.4	31.1	32.8	35	37.2	39.4	42.2	45	47.8	51.1	55	58.3		
55	27.2	28.9	30	31.7	33.9	36.1	38.3	41.1	44.4	47.2	51.1	54.4	58.3			
60	27.8	28.9	31.1	32.8	35	37.8	40.6	43.3	46.7	50.6	53.9	58.3				
65	27.8	29.4	31.7	33.9	36.7	39.4	42.2	45.6	49.4	53.3	57.8					
70	28.3	30	32.2	35	37.8	40.6	44.2	48.3	52.2	56.7						
75	28.9	30	33.3	36.1	39.4	42.8	46.7	51.1	55.6							
80	28.9	31.7	34.4	37.8	41.1	45	49.4	53.9								
85	29.4	32.2	35.6	38.9	43.3	47.2	52.2	57.2								
90	30	32.8	36.7	40.6	45	50	55									
95	30	33.9	37.8	42.2	47.2	52.8										
100	30.6	35	39.4	44.4	49.4	55.6										

CAUTION
EXTREME CAUTION
DANGER
EXTREME DANGER

LIKELIHOOD OF HEAT DISORDERS WITH PROLONGED EXPOSURE OR STRENUOUS ACTIVITY

Source: http://www.nws.noaa.gov/os/heat/heat_index.shtml

NOAA's heat stress index rises to "Extreme Danger" at temperatures over 35 degrees with around 80% humidity.

The Sunshine Coast already experiences humidity of over 70% for a large proportion of the year. From September 2017 to September 2018 there were 94 days, concentrated in summer, with a relative humidity of 70% or above at 3pm in the Sunshine Coast, and 44 days over 80% humidity.[5]

A future that combines such high humidity levels with an increase in the frequency of days over 35 degrees represents a serious threat to the wellbeing of the Sunshine Coast's and Australia's wider population. As well as an increase in heat related deaths and illness, the rise in extreme heat increases irritability and psychological stress.[6] Hot weather affects patterns in domestic violence,[7] interrupts sleep patterns and reduces capacity and willingness to exercise. All carry broad ramifications, such as increased accident risk, sedentary life style induced diabetes and cardio vascular disease.[8,9] Tracking and minimising the way climate change is affecting the number of hot days is of direct interest to the wellbeing of local communities, particularly in hot areas such as the Sunshine Coast region.

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[5] BoM (2018) *Daily Weather Observations*, http://www.bom.gov.au/climate/dwo/IDCJDW4081.latest.shtml

[6] Queensland Health (2015) *Heatwave Response Plan* https://www.health.qld.gov.au/__data/assets/pdf_file/0032/628268/heatwave-response-plan.pdf

[7] Auliciems and Di Bartolo (1995) *Domestic Violence in a subtropical environment: police calls and weather in Brisbane.* International Journal of Biometeorology 39 (1).

[8] Kjellstrom T et al (2009) *The Direct Impact of Climate Change on Regional Labor Productivity.* Archives of Environmental & Occupational Health 64 (4).

[9] World Health Organisation (2017) *Preventing noncommunicable diseases (NCDs) by reducing environmental risk factors*, http://apps.who.int/iris/bitstream/10665/258796/1/WHO-FWC-EPE-17.01-eng.pdf?ua=1

Hot days in the Sunshine Coast

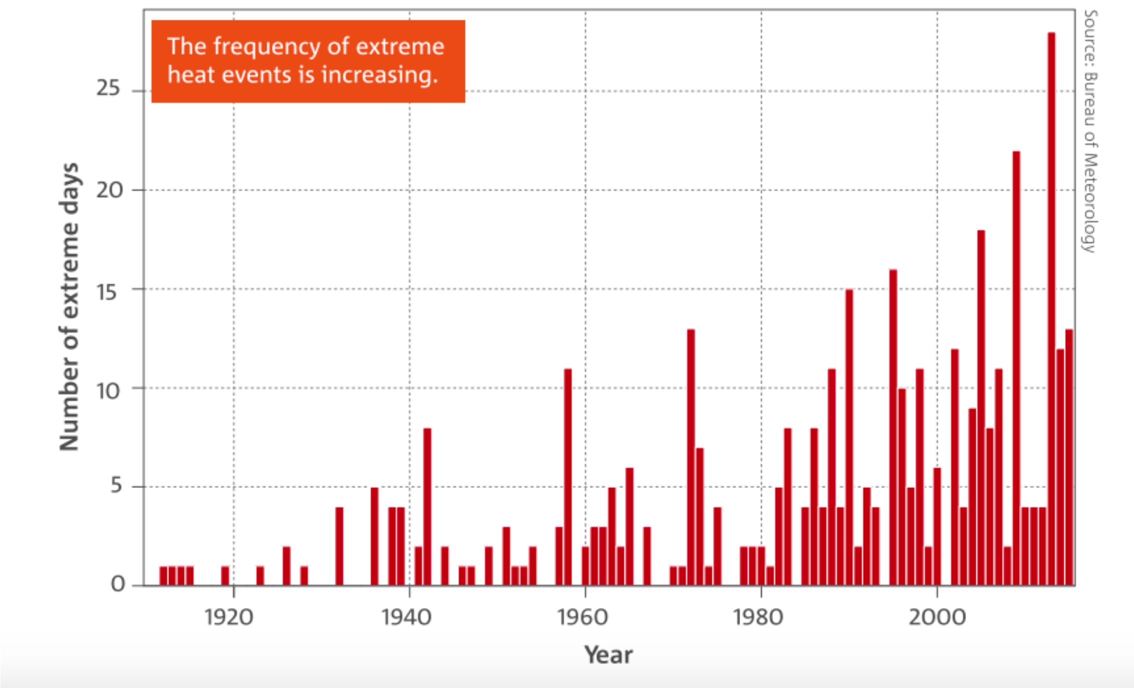
In Australia and globally there has been a clear trend of increasing temperatures and extreme heat events that are attributable to global warming.

The increase in extreme heat events across Australia as a whole is shown in Figure 2 below. This Bureau of Meteorology graph shows the annual number of days exceeding the 99th percentile of each month from 1910–2015.

The Bureau of Meteorology clearly attributes this trend to global warming.

> As the global climate system has warmed, changes have occurred to both the frequency and severity of extreme weather. In Australia, the most obvious change has been an increase in the occurrence of record-breaking heat.[10]

Figure 2: Frequency of extreme heat days, Australia.

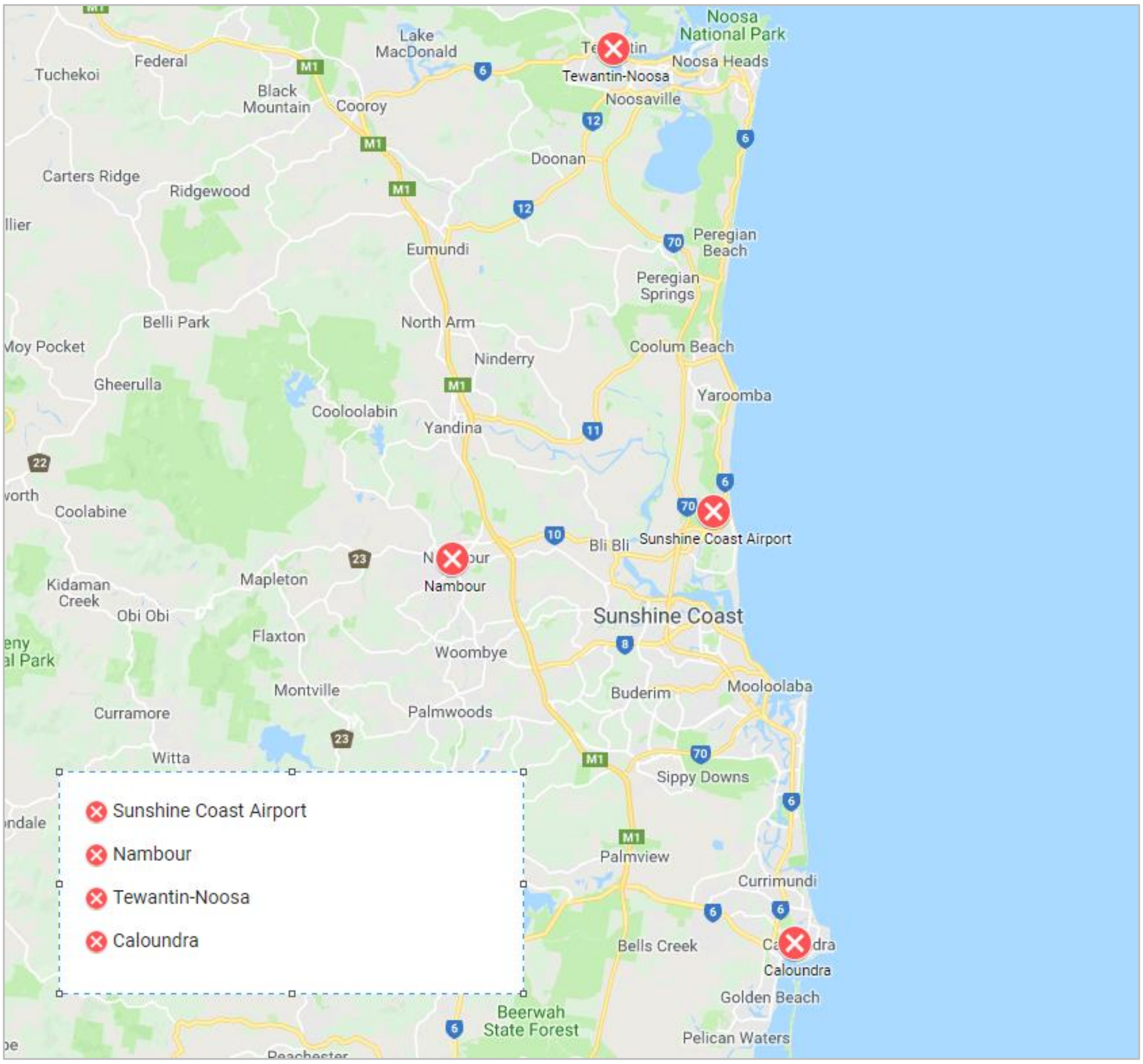


Source: BoM (2016) *State of the Climate*

[10] BoM (2016) *State of the Climate,* http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf

The CSIRO and Bureau of Meteorology have current temperature records from different locations in the Sunshine Coast region. In the map in Figure 3, the tacks mark the sites where these stations are situated.

Figure 3: Map of the Sunshine Coast Region

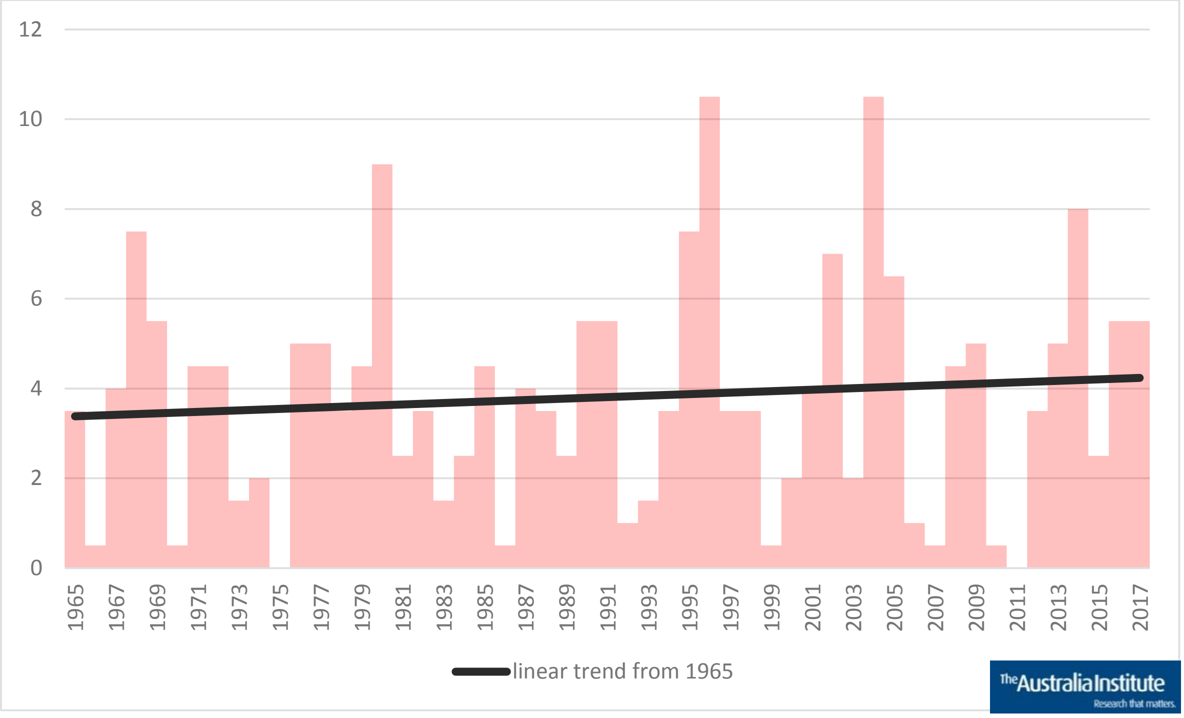


Source: Prepared on Google Maps by The Australia Institute

The data gathered from the different stations varies in type and how long they have been kept. The CSIRO publishes future threshold projections for Tewantin-Noosa, Nambour and Caloundra. Tewantin-Noosa and Nambour have maintained temperature records parallel from 1965. However there is no BoM weather station at Caloundra. The Sunshine Coast Airport has only maintained weather station data since 1995. The annual average at this Airport station has consistently been 1.8 days a year.

The annual number of days over 35 degrees in each year shown in Figure 4 below is the average of the Nambour and Tewantin-Noosa stations from 1965.

Figure 4: Average annual number of days over 35 degrees at Tewantin-Noosa and Nambour, 1965–2017



Source: Bureau of Meteorology (n.d.) *Climate data online,* http://www.bom.gov.au/climate/data/index.shtml

Table 1 below demonstrates that although the average number of days recorded at these weather stations has remained relatively consistent, there has been an upwards trend.

Table 1: Average number of days per year above 35 degrees

Years	Average days over 35 degrees
1965–1977	3.4
1978–1987	3.6
1988–1997	4.5
1998–2007	3.8
2008–2017	4

Source: Bureau of Meteorology (n.d.) *Climate data online,* http://www.bom.gov.au/climate/data/index.shtml

Projected increases in days over 35 degrees

The number of days over 35 degrees in the Sunshine Coast is expected to increase dramatically in the coming decades if global emissions continue to rise according to CSIRO and BoM climate modelling.

The CSIRO use eight climate models to project temperature extremes into the future. All climate models use different methods for understanding the complex climate system, and as such provide a range of projections. The models used by the CSIRO are selected on the basis of how well they simulate the current climate.[11]

Our analyses in Figures 5 and 6 use all eight climate models selected by the CSIRO, and present the full range of their projected increases in days over the various temperature thresholds according to two different emissions scenarios. These Figures also mark the average of the projections, as well as the highest and lowest ones.

The two scenarios the projections are based on are from the United Nations Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCPs), which are two of four scenarios of various levels of concentrations of greenhouse gases in the atmosphere.

The historical data used to make projections by the CSIRO–BoM models is not that of the stations shown in Figure 4, but is instead a time-series from the Australian Water Availability Project (AWAP) where the average temperature was compiled in 5x5km spatial grids between 1981–2010 at Tewantin-Noosa, Nambour and Caloundra.[12]

These models, and the projections built off them, observed only one to two days a year over 35 degrees historically which is lower than the averages taken at Tewantin-Noosa and Nambour, but consistent with the average at Sunshine Coast Airport station since 1995.

Figure 5 below lays out the CSIRO predictions to 2090 of the two scenarios:

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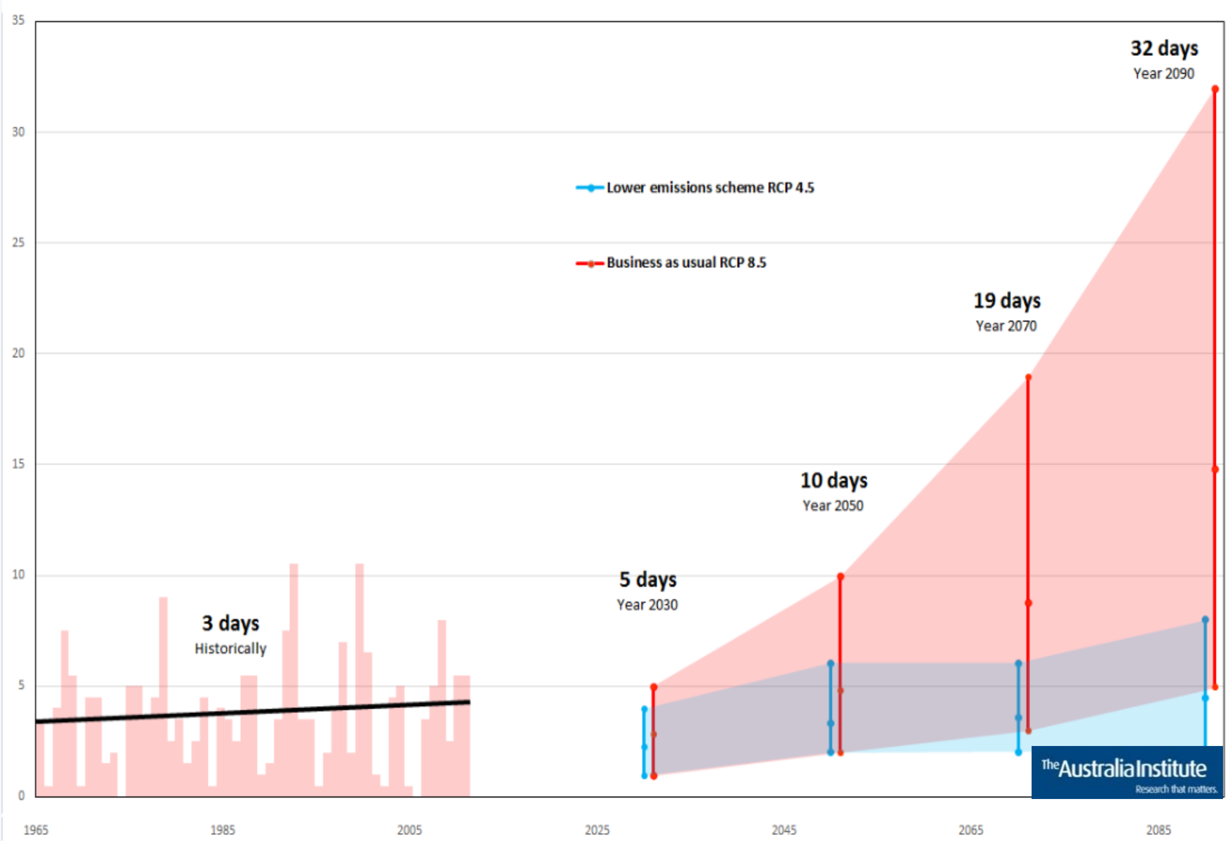
[11] CSIRO (n.d.) *Modelling choices and methodology,* Climate Change in Australia, https://www.climatechangeinaustralia.gov.au/en/climate-projections/about/modelling-choices-and-methodology/

[12] CSIRO and Bureau of Meteorology (2015) *Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report*, CSIRO and Bureau of Meteorology.

Figure 5: Forecast annual number of days over 35 degrees the Sunshine Coast



Source: CSIRO and Bureau of Meteorology (2015*) Climate projections: Climate threshold calculator*, https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/threshold-calculator/

Figure 5 displays the scenario 'RCP 8.5', which is the highest of the four scenarios of global emissions outlined by the IPCC in their 2014 Fifth Assessment. It reflects the business as usual (BAU) scenario, which most closely resembles the current global trajectory as emissions still continue to increase and insufficient action is taken.[13]

Under the BAU scenario of greenhouse emissions, the CSIRO projects that the Sunshine Coast could experience as many as ten days over 35 degrees per year in 2050, and 32 days per year by 2090. This would be a near tenfold increase from the BoM average of 3.4 days from 1965–1977. The range of the eight climate model projections under BAU is shaded in red.

Figure 5 also shows the projected number of days over 35 degrees under the RCP 4.5 scenario where strong emission reduction is achieved. The RCP 4.5 pathways require decisive reduction in emissions. If this is achieved, the average of the CSIRO climate

[13] Le Quere et al (2017) *Global carbon budget 2017,* Earth Syst Sci Data 8.

models expects the number of days over 35 degrees per year to be lower than in a BAU trajectory – staying at 3.3 days over 35 degrees per year in 2050, 3.6 days per year in 2070, and 4.5 days per year in 2090. While this still has significant inherent risk, substantial additional harm could be avoided. The range of the eight climate model projections that assume a substantial reduction in emissions is shaded in blue.

Urban Heat Island effect in the Sunshine Coast

Highly urbanised areas create an environment that is divergent from the surrounding rural areas. Research has found that due to urban structures like concrete and skyscrapers - along with roads, pavement, and diminished vegetation cover – cities becomes warmer as more heat is absorbed in the materials during day and and then relased at night, which increases night-time temperatures.[14]

This creates an Urban Heat Island effect (UHI) not just on these surfaces but also in the atmosphere. This is more prominent during summer as temperatures rise. During the daytime UHI causes exposed surfaces like roofs to heat to temperatures up to 50 degrees hotter than the air while rural areas remain closer to the atmospheric temperatures, creating an 'island' effect in cities.[15]

It is at night though when UHI has its most negative influence on atmospheric heat extremes. Heat absorbed in urban structures during the day is slowly released after sunset compared to heat in vegetated areas. This produces much higher temperature shifts in the air overnight than in equivalent rural areas.[16] On a clear calm night, the US Environmental Protection Agency states that the temperature difference can be as high as 12 degrees between urban and rural areas.[17]

The overnight effects of UHI are consistent across climate zones and scenarios. Coastal cities like the Sunshine Coast also suffer from UHI despite sea breeze.[18] Studies also raise the concern that night temperature extremes carry the higher risks of mortality as people are unable to recover from daytime heat stress .[19]

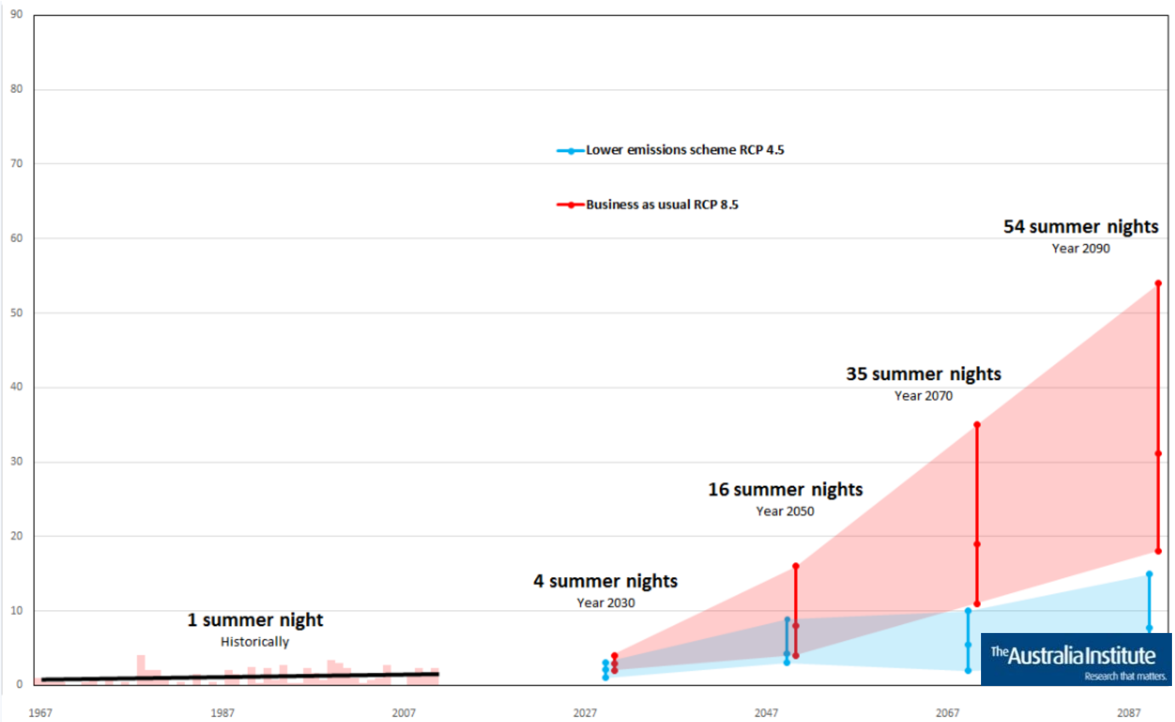
[14] Sharifi and Soltani (2017) *Daily variation of urban heat island effect and its correlations to urban greenery: A case study of Adelaide,* Frontiers of Architectural Research 6.
[15] United States Environmental Protection Agency, *Learn About Heat Islands,* https://www.epa.gov/heat-islands/learn-about-heat-islands
[16] Argueso et al. (2015) *Effects of City Expansion on Heat Stress under Climate Change Conditions,* PLoS ONE 10.
[17] United States Environmental Protection Agency, *Learn About Heat Islands,* https://www.epa.gov/heat-islands/learn-about-heat-islands
[18] Santamouris et al. (2017) *Urban Heat Island and Overheating Characteristics in Sydney, Australia – an analysis of multiyear measurements,* Sustainability 9.
[19] Zhao et al. (2018) *Interactions between urban heat islands and heat waves,* Environmental Research Letters 13.

Projected extreme heat over summer nights with UHI

Due to UHI and its effects on atmospheric heat over night, the number of hot days on the Sunshine Coast will be accompanied by an even greater increase in the frequency of extreme summer nights. Part of this more rapid warming at night is characteristic of the climate system however as night-time temperatures are more sensitive to a build up of greenhouse gases.[20]

The BoM classifies nights with extreme heat as those with a minimum temperature of 25 degrees. A further indication of the projected distribution of extreme heat nights into the future can be gained from examining the CSIRO and BoM datasets. The CSIRO AWAP summer projections are based off December–February having 90.25 days – and for the sites on the Sunshine Coast the historical average is one summer night with a minimum temperature of 25 degrees between 1981–2010 as shown in Figure 6:

Figure 6: CSIRO–BoM projections of frequency of summer nights over 25 degrees



[20] Davy et al. (2016) *Diurnal asymmetry to the observed global warming*. International Journal of *Climatology*.

Source: CSIRO and Bureau of Meteorology (2015) *Climate projections: Climate threshold calculator*, https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/threshold-calculator/

Figure 6 demonstrates the dramatic projected increase in the frequency of extreme heat nights in summer in the highly urbanised areas of the Sunshine Coast region.

Under a BAU scenario on greenhouse emissions, the CSIRO and BoM estimate that the Sunshine Coast could experience as high as one in six summer nights over 25 degrees by 2050, almost one in three by 2070 and 60% – nearly two thirds – of summer nights in extreme heat by 2090.

Under a RCP 4.5 pathway with significant emissions reduction, the amount of these extreme heat nights would not reach anywhere near the peak of the BAU scenario. Even under the highest projections, the RCP 4.5 scenario tops out below the lowest projection of BAU at ten days by 2070, and fifteen by 2090. The average of these climate models also predicts under eight of these nights a summer by 2090, avoiding substantial harm to the people of the Sunshine Coast.

The high incidence of extreme summer nights combined with the significant increase in projected heat days make for a climate very dangerous to human health and wellbeing.

Note the CSIRO-BoM projections are drawn from the average amount of summer nights in extreme heat per year in the Tewantin-Noosa and Caloundra sites, but excludes the less dense Nambour site to represent the effect of UHI.

Health and productivity impacts of extreme heat

The impact of extreme heat on human health, particularly over extended periods of time, is severe. Although people living in hot areas do acclimatise to help cope with extreme temperatures, there are limits.[21] A large increase in days over 35 and nights over 25 degrees will push past those limits.

The health impacts of increasing extreme heat can include both direct heat illnesses such as heat exhaustion and indirect illnesses such as heart failure and even death. As climate change worsens this can be expected to put more vulnerable people at increasingly greater risk.

As we operate during the day we produce heat that needs to be released from our bodies. Sweating exchanges heat from the body to the atmosphere, but this heat exchange process diminishes significantly beyond 35 degrees and, as a result, body temperature rises.

WorkSafe Queensland lists a range of illnesses arising directly from extreme temperatures from mild cramps, rashes, and dehydration to severe injuries such as heat stroke, exhaustion and even death if treatment is delayed.[22]

Those demographics that are most vulnerable include the elderly, the very young, and those with pre-existing health conditions. Illnesses such as angina, kidney disease, and diabetes are at higher risk of being triggered or exacerbated when people are unable to maintain a safe body temperature.[23]

People suffering from mental disorders are also vulnerable. This vulnerability to extreme heat can result from altered behavioral responses to high temperatures or the impact of medications.

As stated earlier, irritability and psychological stress also increase in heat. When hot days are combined with hot nights, heat load and stress carries over and the body has

[21] Hanna and Tait (2015) *Limitations to thermoregulation and acclimatisation challenges human adaptation to global warming,* Int J Environ Res Public Health 12.

[22] WorkSafe Queensland (n.d.) *Health effects,* https://www.worksafe.qld.gov.au/injury-prevention-safety/hazardous-exposures/heat-stress/health-effects

[23] Hanna et al. (2016) *The silent killer: Climate Change and the Health Impacts of Extreme Heat,* The Climate Council, https://research-management.mq.edu.au/ws/portalfiles/portal/72578140/72578105.pdf

no opportunity to cool down and recover. Studies show that there is an association between the mortality of not just stroke patients but also the general population and high night temperatures.[24,25] The 'synergistic effect' of night humidity, increased temperatures, and UHI in heatwaves has been estimated in some studies to double general mortality risk by the end of the century under RCP 8.5.[26]

Extreme heat nights also cause increased insomnia and lack of rest. This is exacerbated by the higher relative humidity at overnight time. As sleep is vital for healthy human functioning, a lack of it means more susceptibility to disease, obesity, chronic illness and harm to our psychological and cognitive functioning.[27]

Productivity decreases significantly under these stresses as people are affected with the consequences of extreme heat. Workplace safety and the ability to work declines. This can also be displayed in economic terms as costs rise to account for the lack of labour productivity and changes needed in workplaces.[28]

As the Sunshine Coast is reliant on the services, tourism, construction and retail industries for employment, this would have very detrimental impacts to the region.

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[24] Murage et al. (2017) *Effect of night-time temperatures on cause and age-specific mortality in London,* Environmental Epidemiology 1.

[25] Roye (2017) *The effects of hot nights on mortality in Barcelona, Spain,* International Journal of Biometeorology 61.

[26] Zhao et al. (2018) *Interactions between urban heat islands and heat waves,* Environmental Research Letters 13.

[27] Obradovich et al. (2017) *Nighttime temperature and human sleep loss in a changing climate,* Science Advances 3.

[28] Climate Council (2014) *Heatwaves: Hotter, Longer, More Often,* https://www.climatecouncil.org.au/uploads/9901f6614a2cac7b2b888f55b4dff9cc.pdf

Extreme heat impacts on infrastructure

The effects of extreme heat on infrastructure essential to the Sunshine Coast is also projected to be significant:

- Power and transmission infrastructure around the Sunshine Coast region would be affected by higher sustained temperatures. Levels of peak demand during heat would also rise as people use air conditioning to escape the stress. This would affect the ability of generation to meet demand and increase the incidence of blackouts due to load shedding.
- General water demand would rise while supply would fall, leading to water stress.
- Medical facilities would be under increased strain because of the rise of detrimental health effects.
- Transport infrastructure would more frequently be damaged by intense levels of heat. Bridges, roads, concrete structures and rail lines would all be susceptible to damage from cracking and buckling under stress.
- Homes, businesses, power generators, and public infrastructure would all be under the increased threat of bushfires caused by drier and hotter conditions.[29]

The financial losses and economic cost that result from the effects of these failures and disruptions would affect all the people of the Sunshine Coast region.

[29] Climate Council (2014) *Heatwaves: Hotter, Longer, More Often,* https://www.climatecouncil.org.au/uploads/9901f6614a2cac7b2b888f55b4dff9cc.pdf

Conclusion

An increase in days and nights of temperature extremes will have severe impacts on human health, including increased rates of heat-related deaths.

Given the vulnerability of the Sunshine Coast and the rest of the Queensland to climate change, strong emissions reduction policies are in both the region snd the state's interests.

Fortunately Queensland is in a strong position to implement and benefit from strong climate and energy emissions reduction policies. Queensland is blessed with an abundant solar resource. This presents it with the opportunity to make large reductions in power sector emissions and a particular opportunity for solar rich areas like the Sunshine Coast to benefit from the regional development and employment opportunities of renewable energy.

Increasing gas and coal exports is incompatible with Australia's carbon budget and commitments under the Paris agreement to limit warming to less than 2 degrees. It has been calculated that two thirds of existing fossil fuel reserves need to remain in the ground in order to have even a 50% chance of avoiding 2 degrees of warming.[30]

The recent IPCC Special Report on Global warming of 1.5 degrees found that keeping warming below 15 degrees will be necessary to avoid many devastating impacts, and that to do so the world will need to reach net zero emissions by 2040, or 2055 at the latest. [31]

Australia is one of the highest per capita emitters in the world. Queensland's large and expanding coal and gas export activities are internationally significant and are throwing fuel on the fire, increasing extreme temperatures in a way that will have a devastating impact on the Sunshine Coast region.

There is an urgent need for adaptation measures to cope with increasing extreme heat in many parts of Australia, including the Sunshine Coast. However, unless ultimately there is strong global action on climate change, temperature increases will have a detrimental impact on the region. As a major emitter, it is vital that Queensland and Australia as a whole play our part in achieving these emissions reductions.

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[30] McGlade and Ekins (2015) *The geographical distribution of fossil fuels unused when limiting global warming to 2 °C*, https://www.nature.com/articles/nature14016

[31] IPCC (2018) *Global Warming of 1.5 °C,* http://www.ipcc.ch/report/sr15/