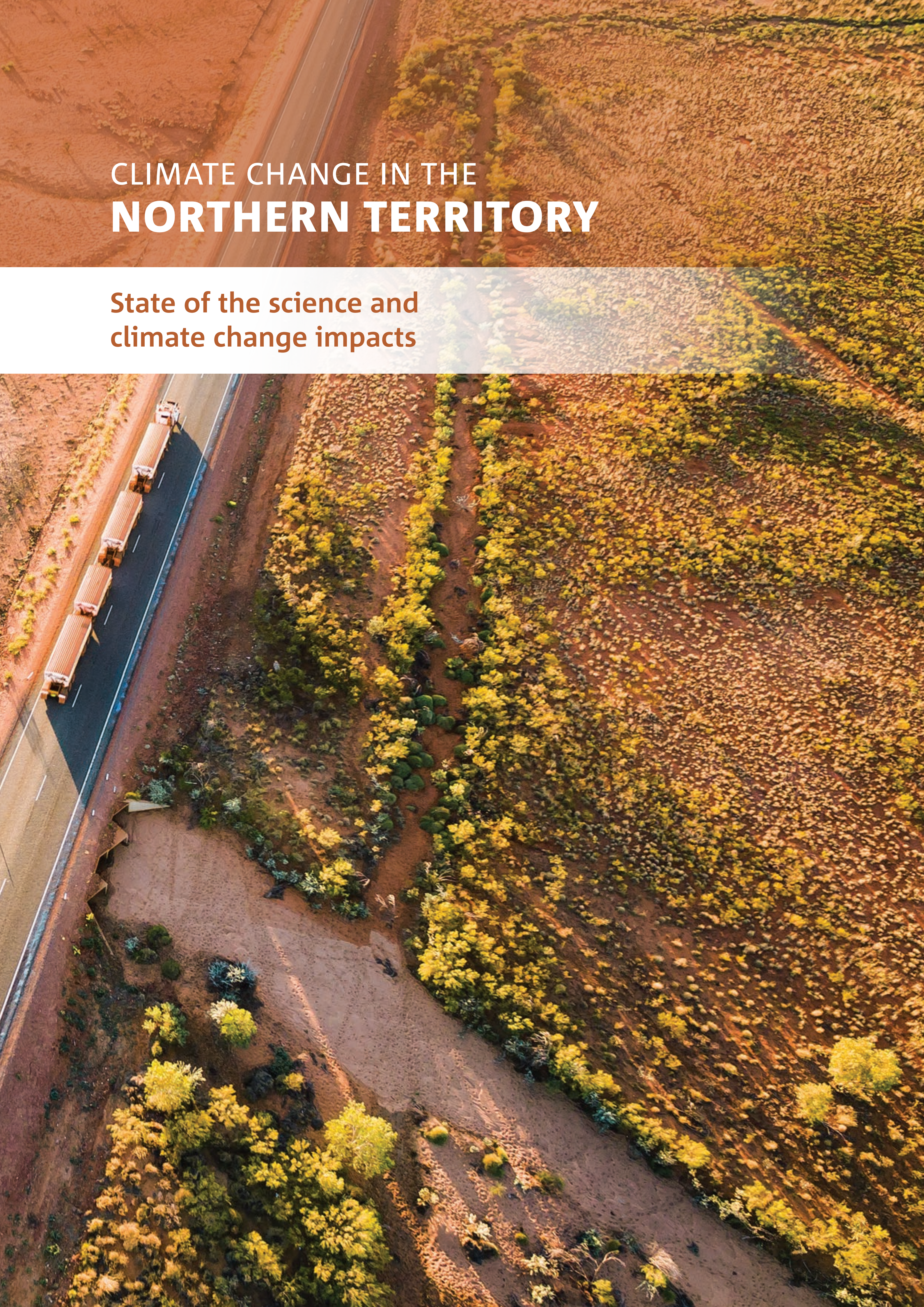
CLIMATE CHANGE IN THE NORTHERN TERRITORY

State of the science and climate change impacts





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AT A GLANCE

This report provides Territorians with an easy-to-understand summary of climate change: what it is, how it's affecting the Territory and what we can do about it.

The global climate is changing

Since the Industrial Revolution in the late 1700s, increasing concentrations of greenhouse gases have enhanced the greenhouse effect of the atmosphere, warming the planet. As concentrations of greenhouse gases increase in the atmosphere, so too does the warming. The consequent imbalance of energy in the climate system is causing it to change at an unprecedented rate.

> See Section 1 for more information

The Northern Territory's climate is changing

The Northern Territory's climate is shaped by weather systems and large-scale climate drivers that vary over space and time. This natural variability is now occurring against the backdrop of global climate change, and the climate of the Northern Territory is changing as a result. The extent of the changes to temperature, rainfall and other climate variables will depend on greenhouse gas concentrations in the atmosphere, with higher concentrations leading to larger changes.

In the future:

- The Northern Territory will continue to get warmer.
- The hottest days in the Northern Territory will be hotter and more frequent, and warm spells will be longer. Frost days will decrease.
- Both wetter and drier futures are plausible, depending on greenhouse gas concentrations.
- Heavy rainfall events will become more intense.
- Time spent in droughts could increase, with changes in drought frequency and intensity.
- Tropical cyclones are projected to become less frequent but more intense.
- Fire weather is projected to become more frequent and harsher.
- Potential evaporation will increase.
- Relative humidity is projected to decrease.
- Mean sea level will continue to rise, and the height of extreme sea levels will increase.
- Sea surface temperature will continue to increase, and the number and intensity of marine heatwaves will increase.
- The ocean around Australia will become more acidic at a rate linked to carbon dioxide concentrations in the atmosphere.

> See Section 2 for more information

Impacts on the Territory

Our environment, communities and economy are all vulnerable to the changing climate. Many aspects of Territory life are already being impacted. Identifying and understanding these impacts is critical for planning for the future – to reduce the risk of ongoing or more severe impacts and to identify opportunities for Territorians to build more resilient communities, develop a sustainable economy and maintain healthy natural systems.

> See Section 3 for more information

Responding to change

Territorians need to actively respond to the changing climate in order to maintain sustainable and resilient communities, a healthy environment and a strong economy. Broadly, responding to climate change involves reducing greenhouse gas emissions to limit further change and doing things differently to manage the change that is unavoidable. Individuals, communities, industries and government all have a part to play, and there are a number of resources available to help.

> See Section 4 for more information

1. The global climate is changing

Since the Industrial Revolution in the late 1700s, increasing concentrations of greenhouse gases have enhanced the greenhouse effect of the atmosphere, warming the planet. As concentrations of greenhouse gases increase in the atmosphere, so too does the warming. The consequent imbalance of energy in the climate system is causing it to change at an unprecedented rate.

1.1 The climate system

The climate system is a complex web of five interconnected components and the interactions between them: the atmosphere, the hydrosphere (oceans, lakes, rivers), the cryosphere (ice, snow), the lithosphere (the land) and the biosphere (living things) (Figure 1.1). The interactions between the components are 'forced' by, among other things, energy from the sun and by human activities.

Weather or climate? It's a matter of time

Weather and climate are words often used interchangeably; however, although they are closely related, they are not the same thing. Weather refers to current atmospheric conditions at a particular place and time – what it's like when you look out your window (e.g. sunny, stormy, hot, humid). Climate is the combination of all the weather (from the typical weather to the extremes) for a particular place over decades – usually 30 years. It is often said that climate is what you expect, and weather is what you get!

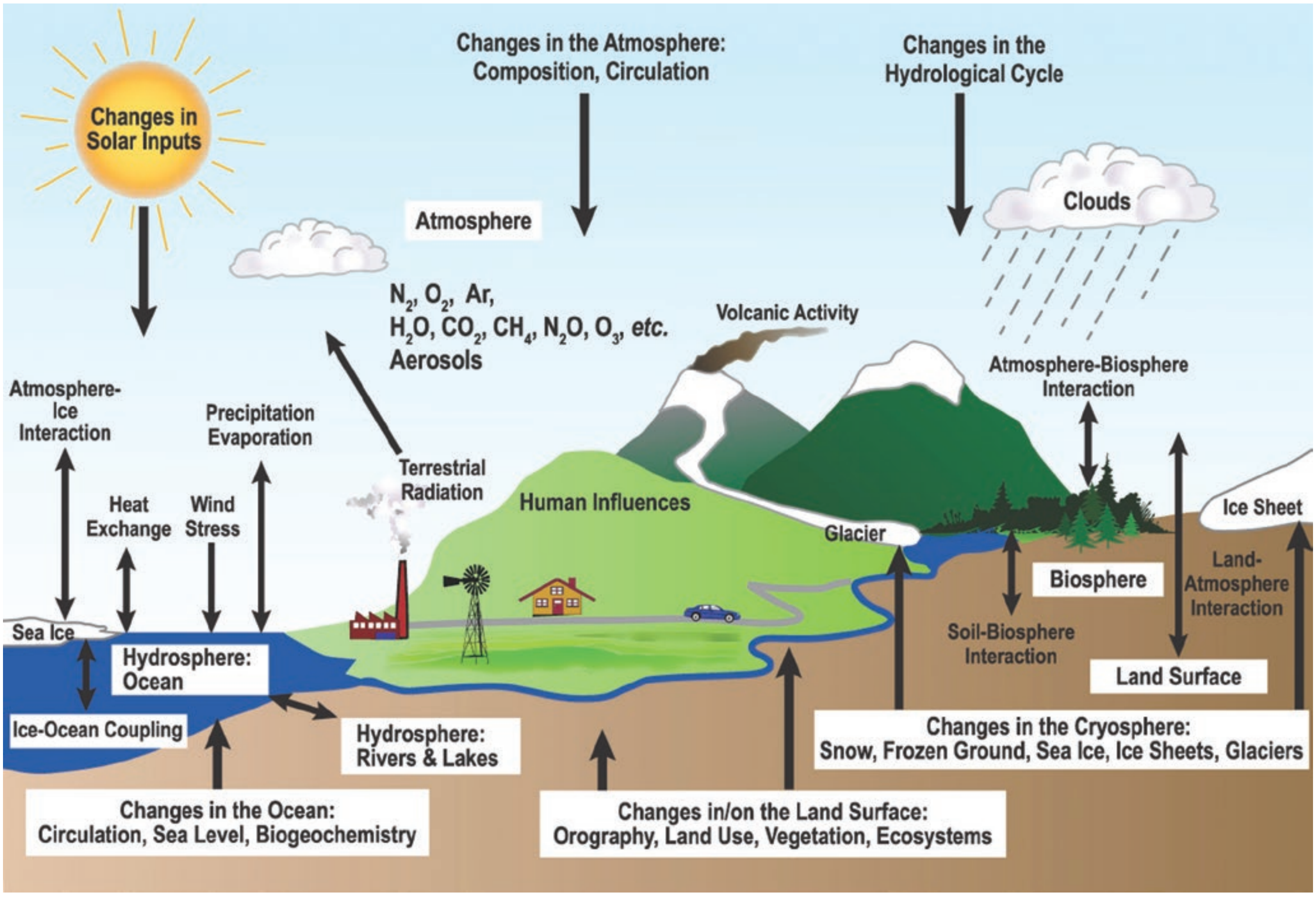


Figure 1.1. The climate system, showing its five components and the key interactions between them (IPCC 2007).

1.2 The greenhouse effect and greenhouse gases

Energy from the sun warms the Earth's surface, causing it to radiate heat in the form of infrared radiation. Most of this heat is absorbed in the Earth's atmosphere and escapes by radiation out to space, but some is trapped by greenhouse gases. The heat that is trapped keeps the Earth warm. This process is called the greenhouse effect (Figure 1.2). Without the greenhouse effect, the average global temperature would be around –18°C and life as we know it would not exist here.

Water vapour, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the most important naturally occurring greenhouse gases. Water vapour is the most abundant greenhouse gas, but its concentration is not directly influenced by human activities and it is relatively short-lived, staying in the atmosphere for only hours to weeks. The amount of water vapour is determined by the temperature of the air, not by emissions from the surface. The other greenhouse gases are long-lived and their concentrations have increased significantly since industrialisation, predominantly through burning fossil fuels. Carbon dioxide accounts for around three-quarters of greenhouse gases emitted into the atmosphere, followed by methane (16%) and nitrous oxide (6.2%) (IPCC 2014).

Measurements taken around the world show that background atmospheric carbon dioxide concentrations are rising, even though there are are seasonal variations (Figure 1.3). These variations depend on location, the uptake and release of carbon dioxide by plants and oceans, and on global atmospheric transport.

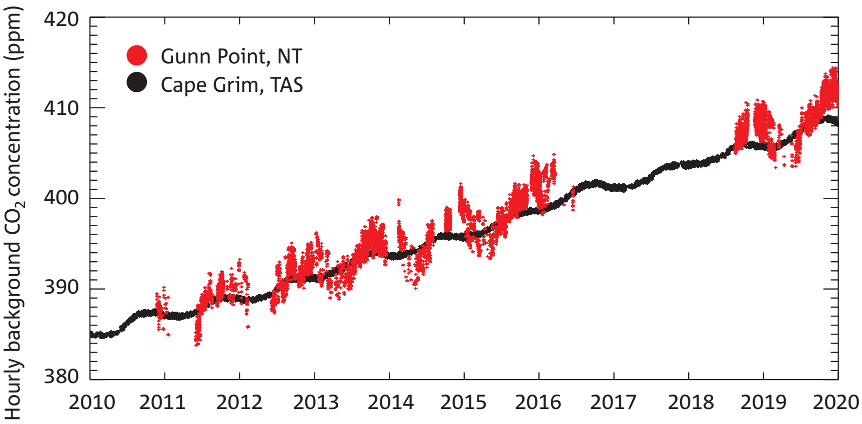


Figure 1.3. Hourly background carbon dioxide as measured at the Northern Territory Baseline Air Pollution Station at Gunn Point and the Cape Grim Baseline Air Pollution Station in Tasmania from 2010 to 2020. (Instruments at Gunn Point were out of commission 2016–2018.)

Greenhouse gases: long lifetimes and lasting effects

It is worth noting that even with cuts in greenhouse gas emissions, the enhanced greenhouse effect will continue for a long time due to the slow removal times of greenhouse gases from the atmosphere. Carbon dioxide increases can persist in the atmosphere for up to thousands of years. Nitrous oxide and methane have much shorter atmospheric lifetimes – around 120 years for nitrous oxide and 12 years for methane – but are both more potent greenhouse gases than carbon dioxide (US EPA, n.d.).

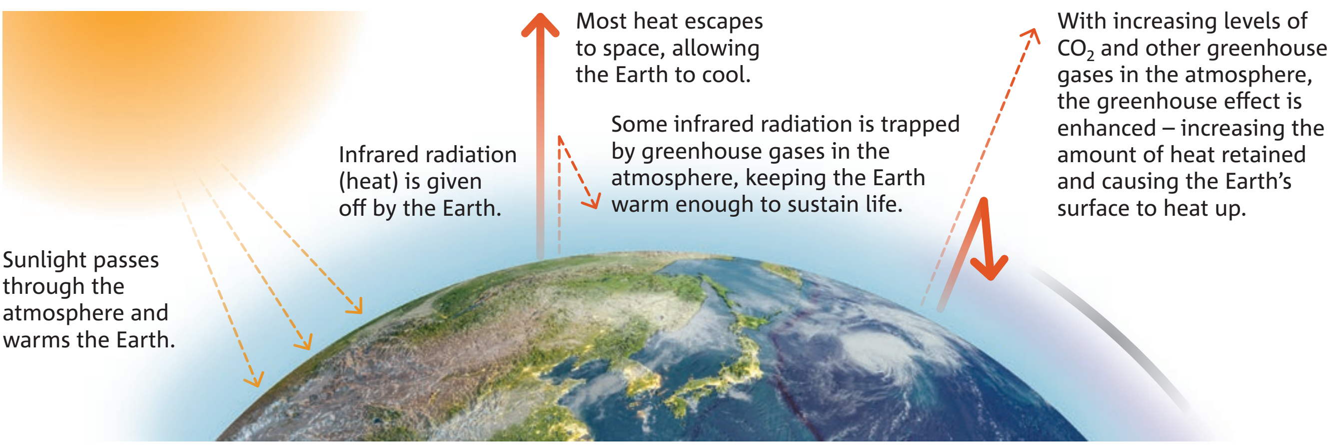


Figure 1.2. The main features of the greenhouse effect. This effect has been enhanced by human activities that have increased the concentration of greenhouse gases in the atmosphere.

1.3 The enhanced greenhouse effect and climate change

Before industrialisation, the average temperature of the Earth was around 15°C. Since then, the increase of greenhouse gases in the atmosphere has enhanced the greenhouse effect, warming the surface of the planet on average by around 1°C (WMO 2020).

The warming is not only increasing air temperatures. Much of the extra heat and carbon dioxide in the atmosphere is being absorbed by the oceans, making them warmer and changing ocean chemistry. As water heats it expands which, along with melting ice sheets and mountain glaciers, is raising sea levels. Atmospheric circulation patterns are being affected, as is the water cycle, which may lead to changes in the frequency and intensity of droughts and extreme rainfall events.

Simulations of the climate with and without greenhouse gases from human activities show that the warming we are experiencing can only occur when we take increasing concentrations of greenhouse gases in the atmosphere into account (Figure 1.4).

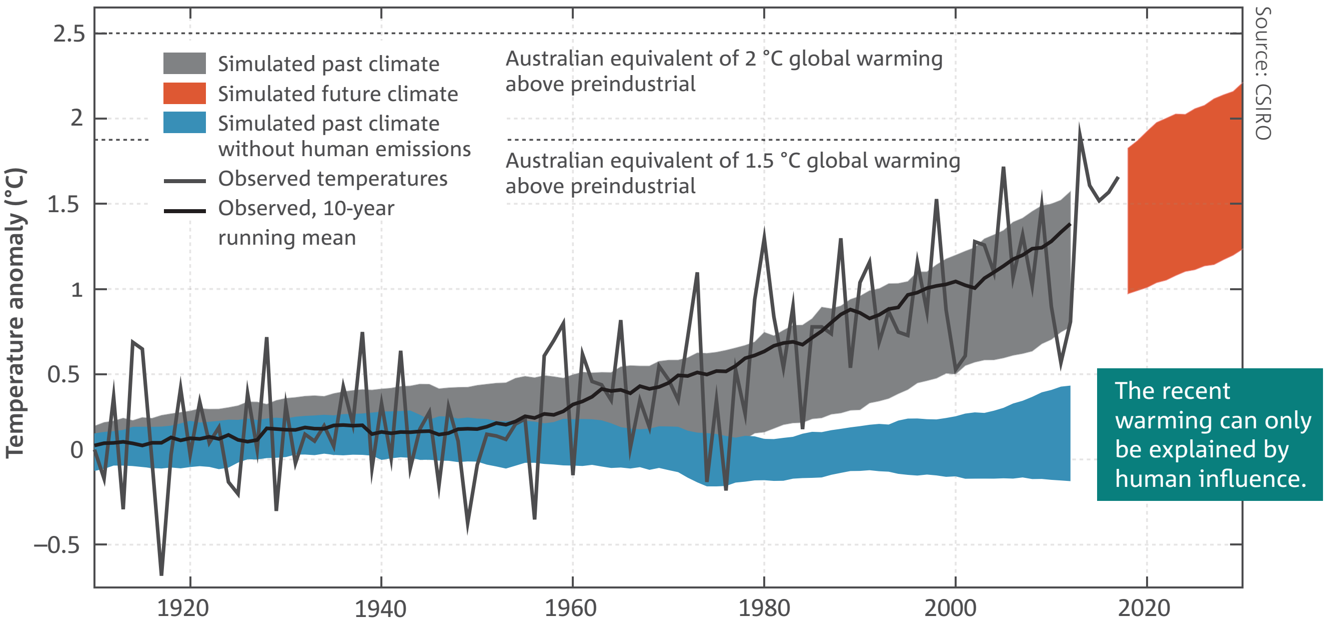


Figure 1.4. Climate simulations without human emissions (blue band) do not match observed changes in the average temperature (grey line). Only simulations that take these emissions into account (grey band) do this. (Source: CSIRO and BoM 2018)

Global assessment and consensus

The Intergovernmental Panel on Climate Change (IPCC) is a United Nations body that assesses climate science from around the world. The results of these assessments are released in major reports that are written and reviewed by hundreds of climate science experts based on thousands of peer-reviewed papers. The most recent assessment report (IPCC 2013) made the following statements:

- Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.
- Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes.
- It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.
- Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

The consensus among climate scientists that global warming is the result of increasing atmospheric greenhouse gas concentrations has also been demonstrated in other studies (Australian Academy of Science 2015; Cook et al. 2013, 2016). The science is indisputable.

1.4 Understanding current and future climate change

The climate the Northern Territory experiences in the future will be determined by the concentration of greenhouse gases in the atmosphere and how the climate system responds to the changes that are occurring, as well as natural climate variability. We can use climate models to simulate a range of future scenarios and provide climate change projections. Projections can be powerful tools for preparing for the future.

1.4.1 Modelling the climate system

Climate modelling allows us to understand past and current changes in climate and to explore the future climate. A climate model is an incredibly complex computer program. It uses mathematical equations based on the laws of physics that govern the climate system and representations of processes such as turbulence, radiation interaction with atmospheric gases and particles, cloud formation and convective processes to simulate the processes and interactions in the climate system.

Global climate models divide the Earth into a 3-D grid, where each grid cell is around 200 kilometres in size. There are typically 40 layers of these cells in the atmosphere and 50 levels down into the ocean. When the model is run, its equations are solved for one point in time for each cell, then those values are used in the equations for the next point in time and so on – much like in the climate system itself, where what happens at one place at one point in time influences what happens there and at adjoining places for the next point in time. In essence, these models are the same types of models that are used to forecast weather.

Due to the enormous number of computations involved, the models are run on supercomputers. Even with such high-powered computing, the models take some time to run. Simulating Australia's climate for one year can take up to a day on our most powerful supercomputers, depending on the model resolution (that is, the size and number of the grid cells the Earth is divided into).

Because of their relatively coarse scale, the simulations from global climate models do not always pick up finer-scale features and processes that influence regional climate, such as mountains or regional weather systems. Regional climate modelling, also called downscaling, can offer additional detail to global climate model simulations. Climate simulations can be downscaled using statistical relationships between the large-scale and regional-scale climate (statistical downscaling) or by nesting a higher resolution regional model within the relatively coarse global model (dynamical downscaling). While downscaling can offer useful regional detail, downscaled simulations still need to be interpreted in the context of the broader global simulations from which they have been derived.

1.4.2 Representing greenhouse gases in modelling

Atmospheric greenhouse gas concentrations have a significant impact on the climate system, and so need to be included in climate modelling. However, future greenhouse gas concentrations are difficult to determine, as greenhouse gas emissions rely on a range of economic, political, social and technological decisions that we cannot foresee.

To overcome this, the climate science community has developed standard scenarios to use in climate modelling. The Australian national climate change projections (see Section 1.4.4) use scenarios called representative concentration pathways or RCPs. These scenarios allow researchers to simulate the climate under four futures, ranging from very strong mitigation of greenhouse gases (RCP2.6) through to ongoing high emissions (RCP8.5) (Table 1.1). The numbers in RCPs refer to radiative forcing, a measure of the balance of the Earth's energy budget – negative radiative forcing indicates cooling, while positive radiative forcing indicates warming (Department of the Environment, n.d.).

In 2019, the global carbon dioxide equivalent (CO_2-e) concentration (which includes carbon dioxide and other greenhouse gases) was already 500 parts per million – and is rising by about 3 ppm per year (NOAA 2020).

Table 1.1. Comparison of representative concentration pathways. Projected temperature and sea-level change are relative to the period 1986–2005.

RCP	Greenhouse gas concentration in 2100 (CO_2 equivalent, parts per million)[1]	Emissions pathway[2]	Projected average temperature change (°C) in 2100[3]	Projected average sea-level rise (m) in 2100[4]
2.6	490	Emissions peak around 2020	0.3 to 1.7	0.26 to 0.55
4.5	650	Emissions peak around 2050	1.1 to 2.6	0.32 to 0.63
6.0	850	Emissions peak around 2080	1.4 to 3.1	0.33 to 0.63
8.5	1370	Ongoing high emissions	2.6 to 4.8	0.45 to 0.82

(Sources: 1. van Vuuren et al. 2011; 2, 3, 4. IPCC 2013)

1.4.3 What climate change projections tell us

While it is tempting to think of climate projections as long-range weather forecasts, this is not the case. Weather forecasts predict the timing and sequence of particular weather events based on forecasting forward from real-time observations. With this constant updating of information checked against observations, weather models can give very accurate and detailed short-term predictions.

Climate projections cannot give this precise detail over the decades and centuries that they cover. While they can simulate a sequence of future weather events, they do not forecast the exact timing of these events. Rather, they provide much broader scale information about how the whole climate system will respond to different future scenarios. They essentially provide the statistics of future weather, such as what the average temperature might be and how daily or monthly temperatures may vary around it. However, there are some limitations.

One is our understanding of the extent of this natural variability. In some cases, it may hide the changes due to global warming, at least for a while. Another is our understanding of how the climate system will respond to global warming. We are not clear about some of the feedbacks in the climate system, such as changes to cloud cover with ongoing warming, and the extent to which they will enhance the changes that we see.

In all, climate change projections provide the best information available on the range of possible future changes, and a full range of projections (from different models and using a range of RCPs) can provide useful insight into likely future climate risks.

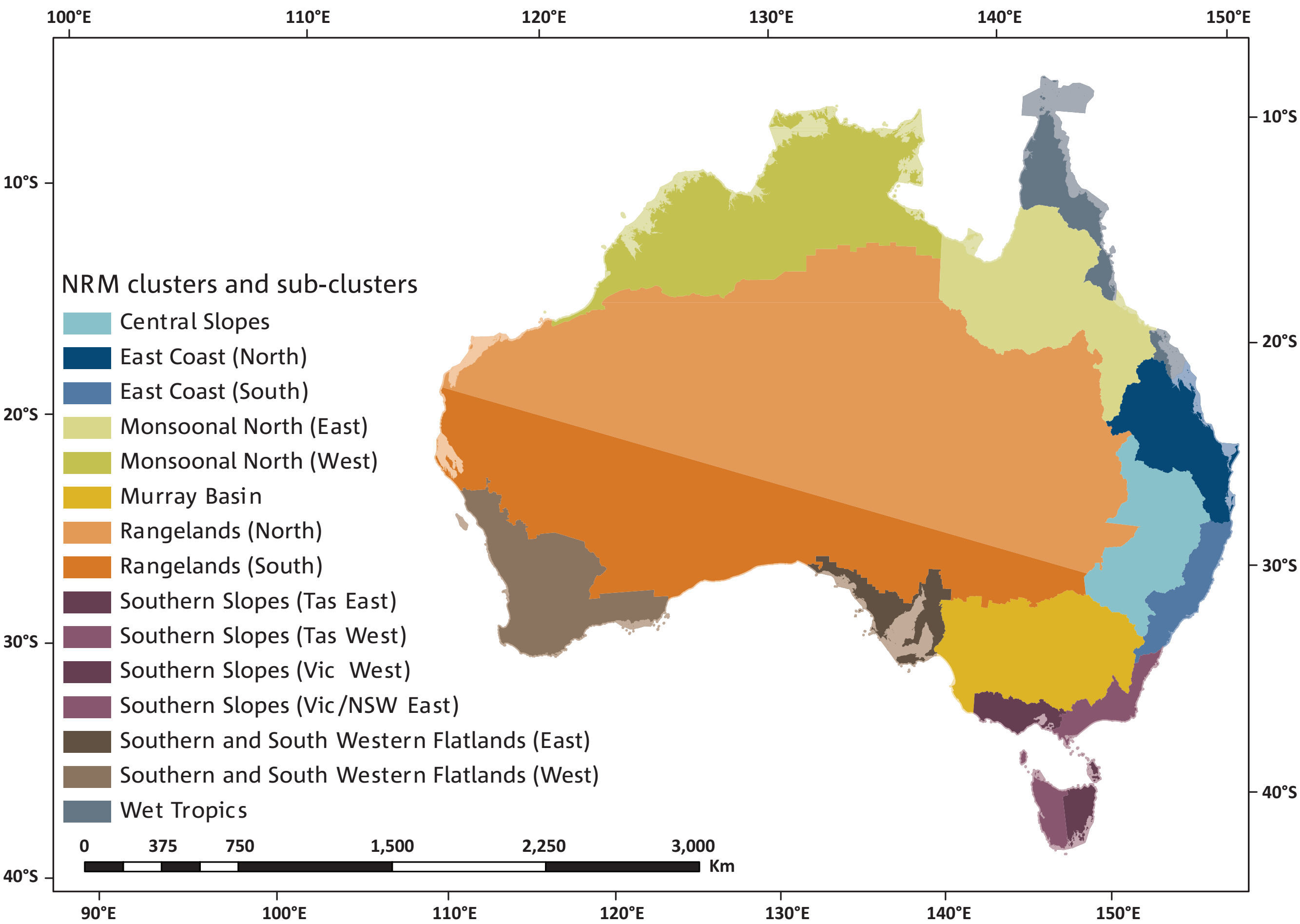


Figure 1.5. Map of Australia showing the natural resource management clusters (and sub-clusters) used in Australia's national climate projections. (Source: Climate Change in Australia)

1.4.4 Australia's national climate change projections

Australia's national climate change projections, Climate Change in Australia (CCIA), were released by the Bureau of Meteorology and CSIRO in 2015. They were developed through the Australian Government's Regional Natural Resource Management Planning for Climate Change Fund. As such, the CCIA projections are based on natural resource management (NRM) regions which have been grouped into eight clusters (Figure 1.5).

The Top End of the Northern Territory corresponds to the Monsoonal North (West) sub-cluster, while the central and southern parts of the Territory are covered by the Rangelands (North) sub-cluster.

This publication uses the CCIA projections unless otherwise noted.

Additional information can be found in the reports for the Monsoonal North (Moise et al. 2015) and Rangelands (Watterson et al. 2015) clusters, which are available along with other projections at www.climatechangeinaustralia.gov.au.

2. The Northern Territory's climate is changing

The Northern Territory's climate is shaped by weather systems and large-scale climate drivers that vary over space and time. This natural variability is now occurring against the backdrop of global climate change, and the climate of the Northern Territory is changing as a result. The extent of the changes to temperature, rainfall and other climate variables will depend on greenhouse gas concentrations in the atmosphere, with higher concentrations leading to larger changes.

2.1 What shapes the Northern Territory's climate?

The Territory's climate is shaped by a number of types of weather systems and large-scale drivers that operate over a range of time scales (Figure 2.1).

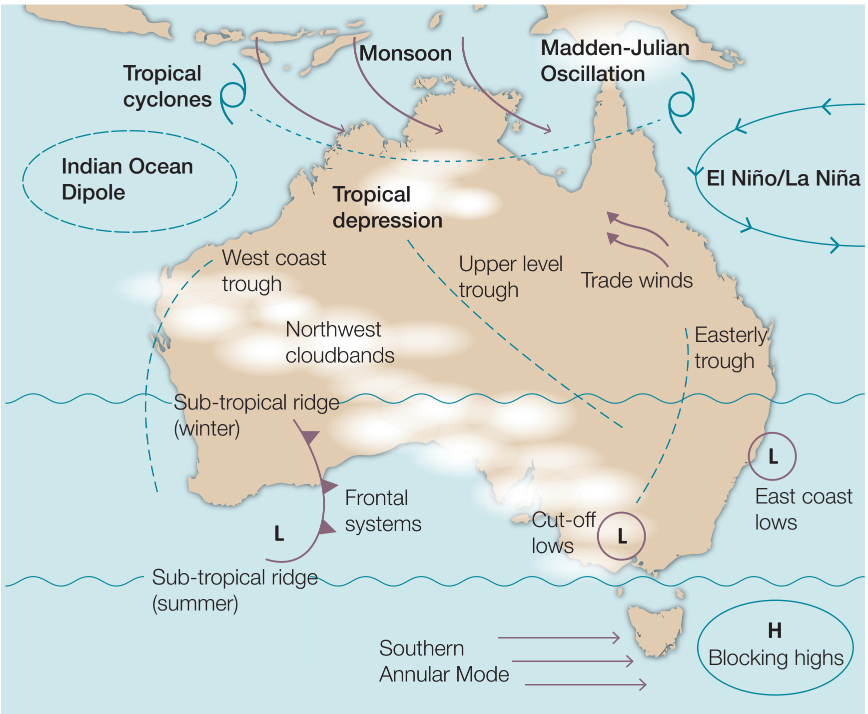


Figure 2.1. There are a number of weather systems and large-scale climate drivers than influence Australia's climate. Features in bold type particularly influence the Northern Territory.

The **monsoon** is responsible for much of the wet season rainfall in the north of the Territory. Around late December each year the easterly trade winds reverse and become moisture-laden westerlies, signalling the monsoon onset (ESCC Hub n.d.). The monsoon persists until around April, going through a series of bursts (wet periods) and breaks (drier periods).

The timing and strength of the monsoon bursts are influenced by the **Madden-Julian Oscillation (MJO)**, a pulse of cloud and rainfall near the equator that recurs every 30–60 days. Monsoon bursts are more likely when the active phase of the MJO is near Australia and breaks are more likely when it is not (ESCC Hub n.d.). **Mid-latitude troughs** are also often associated with the timing of monsoon bursts.

The **El Niño Southern Oscillation (ENSO)** influences rainfall, temperatures and tropical cyclones. During the El Niño phase, there is reduced cloud cover leading to cooler minimum temperatures, reduced rainfall in the monsoon build-up and fewer tropical cyclones. El Niño years tend to have a later monsoon onset and lower rainfall totals overall. Dry season temperatures in the following year are generally higher. During the La Niña phase there are higher minimum temperatures in near-coastal areas due to higher sea surface temperatures, and increased rainfall in the build-up months. Dry season temperatures the following year are generally lower.

The **Indian Ocean Dipole (IOD)** also influences rainfall and temperatures. In the positive phase of the IOD, the Top End experiences dry build-up months. The rangelands experience a dry winter-spring as well as higher maximum temperatures, due to the associated decrease in clouds and rain. In a negative IOD there is higher rainfall over the central Northern Territory in spring, and the increased cloud results in higher minimum temperatures. There is also higher rainfall in the north during the early wet season, and temperatures are warmer due to increased sea surface temperatures near Australia. The IOD may also be related to the monsoon onset (ESCC Hub n.d.).

These large-scale processes will change in a changing climate, although for some, such as the monsoon, the changes are unclear (e.g. Narsey et al. 2020). For others, such as ENSO, we have a better idea of what the changes will look like. For example, El Niño events are projected to become more frequent and severe in the future (Wang et al. 2019). Extreme La Niña events are also projected to become more frequent (Cai et al. 2015). These changes will affect rainfall, drought and extreme climate events in the Territory.

Climate zones in the NT

Due to these large-scale influences and geography, the Northern Territory has three clear climate zones (Figure 2.2).

The tropical north experiences a hot, humid wet season from November to April and a cooler dry season from May to October. The central part of the Territory experiences hot, dry summers and mild winters. In the south, summers are also hot and dry, but winters can be cold.

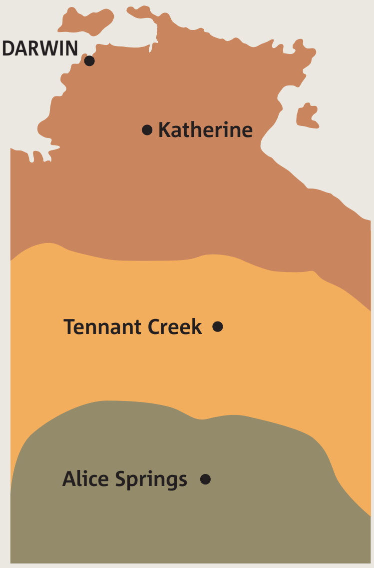


Figure 2.2. Northern Territory climate zones based on temperature and humidity (Source: Bureau of Meteorology)

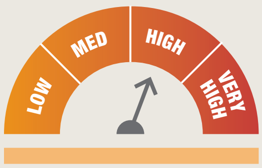
Interpreting climate change projections

The climate projections in this chapter are given for low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions pathways for the near future (2030), mid-century (2050) and end of the century (2090).

The projections are not for individual years in the future. Rather, they represent the 20- or 30-year period centred on 2030, 2050 and 2090 (the length of the period can differ between variables but is noted with each set of projections).

Many of the projections provide a change compared to a given baseline or reference period; for example, 0.14°C increase in average temperature compared to the average temperature for the period 1986–2005. Other projections have already applied the change to a historical value; for example, the projected number of extreme heat days has already added the number of additional days to the historical average.

Confidence ratings reflect how well we understand the physical processes for each variable and how well climate models can simulate them. If the confidence rating is high, then the projected range can be used as a good guide to potential climate change. If the confidence rating is low, then the results are plausible but other possibilities should also be considered possible. We have greater confidence in projections of some variables (e.g. temperature) than others (e.g. rainfall), and greater confidence in projections over large areas and long time periods (e.g. global climate change over a number of decades) than for smaller areas (e.g. regional and national projections) and short time periods (e.g. over periods of less than 10 years). The confidence meters in this report show you how much confidence we have in each of the projections for the Territory.



2.2 Temperature

2.2.1 Average temperature

In the north, average daily temperatures range from 15 to 33°C in the dry season (May to October) and 21 to 36°C in the wet season (November to April).

In the central region of the Northern Territory average daily summer temperatures range from 21 to 39°C, while winter is 6 to 24°C (Figure 2.3).

In the south, average daily temperatures range from 18 to 39°C in summer and 3 to 27°C in winter.

Since the middle of last century there has been a clear warming trend in the Territory, with many more hotter-than-average than cooler-than-average years (Figure 2.4).

> People aged 40 who have spent their entire life in the Territory have only experienced nine cooler-than-average years in their lifetime. Seven-year-old Territorians have lived through five Australian prime ministers but no cooler-than-average years.

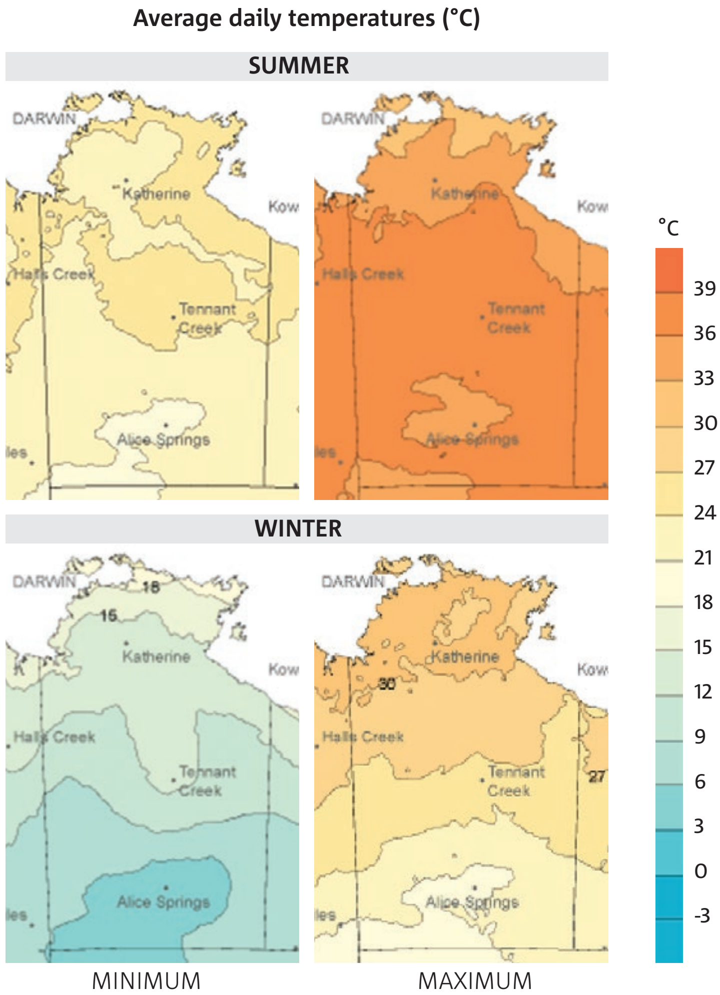


Figure 2.3. Average daily minimum and maximum temperatures for summer and winter in the Northern Territory over the period 1961 to 1990 (Source: Bureau of Meteorology).

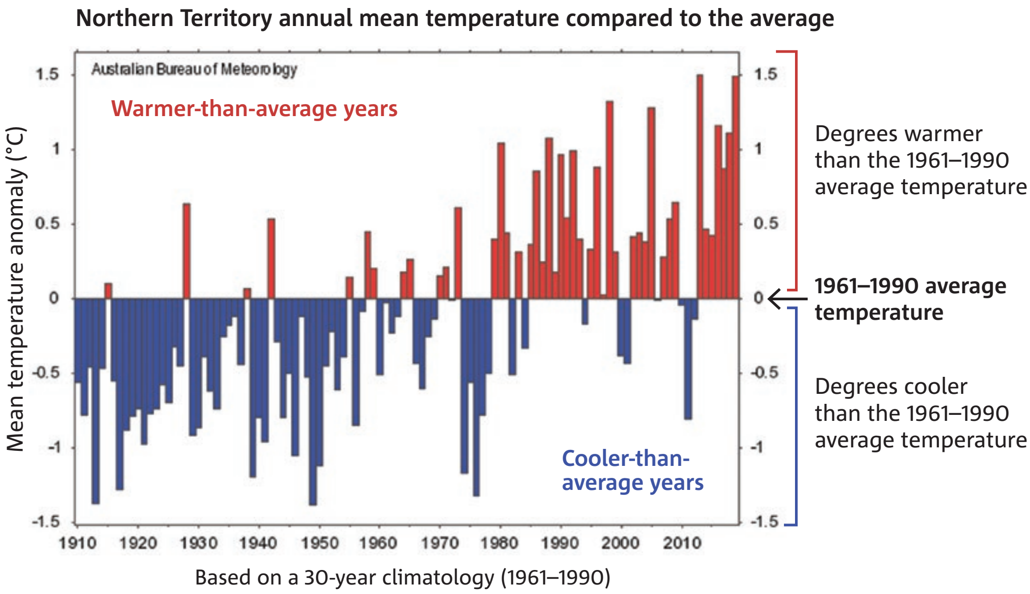
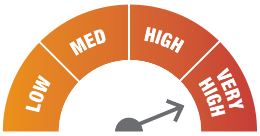


Figure 2.4. The Northern Territory's annual mean temperature difference from the 1961–1990 average for years from 1910 to 2019. Blue bars represent cooler-than-average years, while red bars are hotter-than-average-years.
(Source: Bureau of Meteorology)



The Northern Territory will continue to get warmer.

In the Top End, the near future (2030) will see warming around 0.5 to 1.4°C compared to the average for the period 1986–2005, with very little difference between emissions scenarios. By mid-century (2050), warming will range from 0.7 to 1.6°C under a low emissions pathway to 1.4 to 2.4°C under high emissions. At the end of the century (2090) warming will range from 0.6 to 1.8°C under low emissions to 2.8 to 5.1°C under a high emissions pathway.

Near future warming in the central and southern Territory is similar to the Top End at around 0.6 to 1.5°C, again with very little difference between emissions scenarios. Mid-century warming ranges from 0.7 to 1.6°C under low emissions to 1.4 to 2.4°C following a high emissions pathway. By the end of the century, the central and southern part of the Territory may experience warming of 3.1 to 5.6°C under a high emissions scenario.

How are we tracking?

Temperature observations have been tracking within the projected range to date (Figure 2.5), suggesting the projections are credible so far. We expect individual years to be cooler and hotter than this trend, which is also reflected in Figure 2.5.

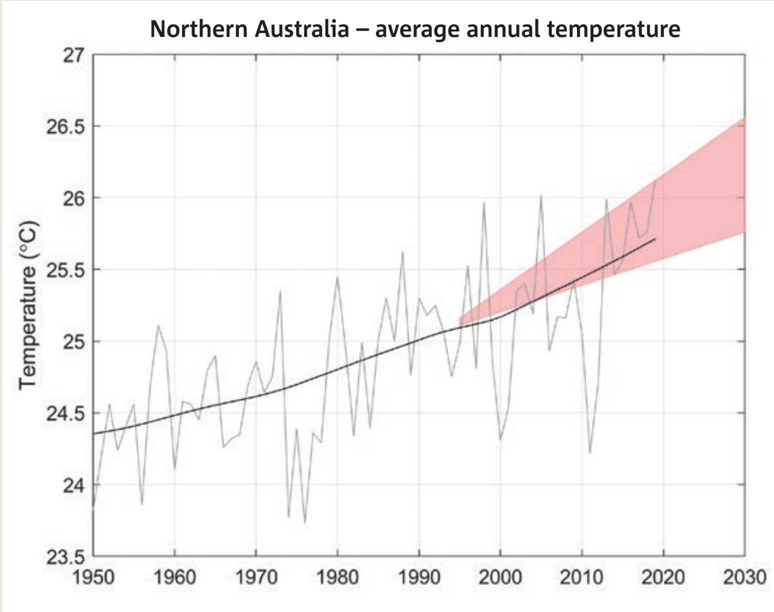


Figure 2.5. Average annual temperature in northern Australia as a whole (north of 26°S) for each year since 1950 (thin line) and the underlying trend (thick line) with the projected range of change for 1986–2005 to 2020–2039 under any emissions scenario from Climate Change in Australia added as a pink range. (The trend shows a 41-year lowess fit (Hawkins et al. 2020), observations are from ACORN-SATv2 dataset.)

Table 2.1. Annual mean temperature change for the near future, mid-century and end of the century under low, medium and high emissions pathways compared to the 1986–2005 average.

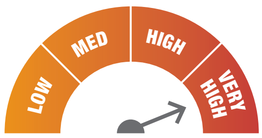
	Annual mean temperature change (°C) from 1986–2005 average								
	2030			2050			2090		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Top End Monsoonal North (West)	0.8 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.6)	1.3 (1.0 to 1.8)	1.8 (1.4 to 2.4)	1.0 (0.6 to 1.8)	1.8 (1.3 to 2.8)	3.7 (2.8 to 5.1)
Central and southern NT Rangelands (North)	1.0 (0.6 to 1.4)	1.0 (0.6 to 1.5)	1.1 (0.8 to 1.5)	1.2 (0.8 to 1.7)	1.5 (1.0 to 2.1)	2.1 (1.5 to 2.6)	1.1 (0.6 to 1.9)	2.1 (1.5 to 3.1)	4.4 (3.1 to 5.6)

A full table of projected changes in annual and seasonal minimum, maximum and average temperature is included in the appendix.

2.2.2 Extreme temperatures

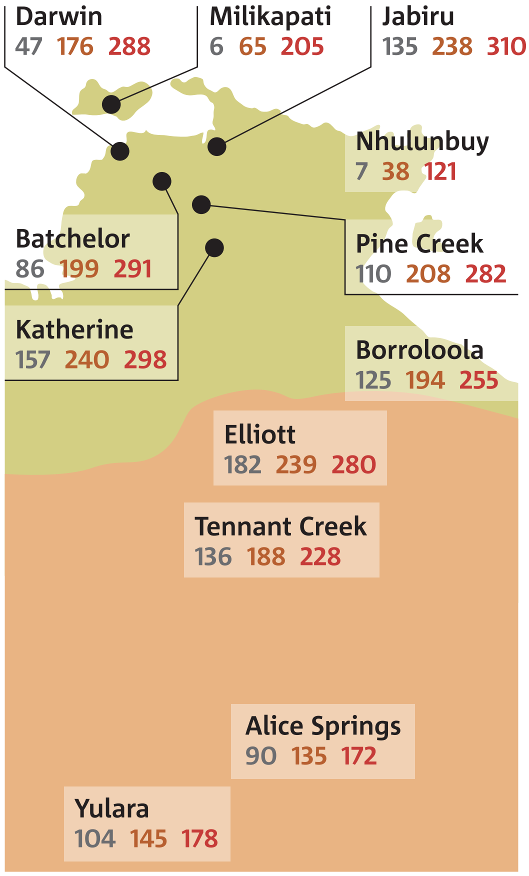
Extreme heat

Extreme temperatures are becoming more common in the Northern Territory (Figure 2.6, Table 2.1).



The hottest days in the Northern Territory will be hotter and more frequent, and warm spells will be longer.

By the middle of the century, the number of days a year over 35°C will at least double in many places across the Territory (Figure 2.7). The number of days over 40°C will also increase considerably.



Annual average number of days over 35°C under a high emissions pathway

Historical 1981–2010

Mid-century 2036–2065

End of the century 2075–2104

Figure 2.7. Projected number of annual average number of days over 35°C for the middle (orange) and end of the century (red) compared to the historical (grey) under a high-emissions (RCP8.5) pathway. Green shading indicates Monsoonal North projections region, orange is Rangelands.

A full table of projections for annual days over 35°C and 40°C for the 12 centres in Figure 2.7 is included in the appendix.

Table 2.2. Comparison of the average annual number of hot days in Darwin, Tennant Creek and Alice Springs between the periods 1959–1988 and 1989–2018 (BoM et al. 2019a, 2019b, 2019c)

	Darwin		Tennant Creek		Alice Springs	
	Days above 30°C	Days above 35°C	Days above 38°C	Days above 44°C	Days above 38°C	Days above 44°C
1959–1988	295	7	39	0	41	4
1989–2018	327	14	48	7	49	24

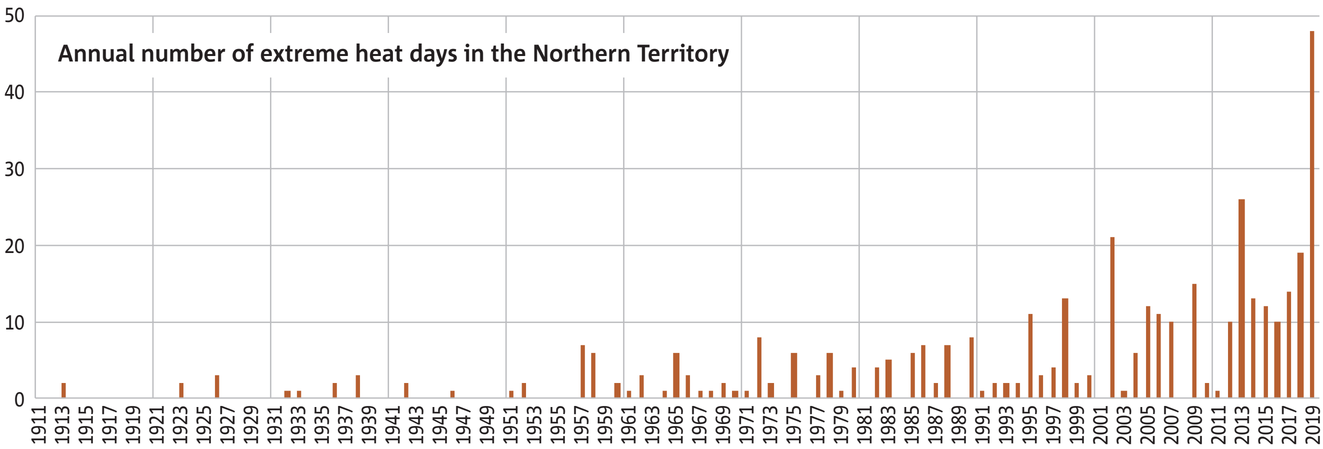
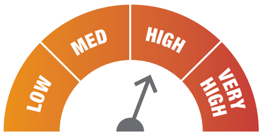


Figure 2.6. Number of days each year where NT area-averaged daily mean temperature is above the 99th percentile of each month (Data: Bureau of Meteorology)

Extreme cold

The southern part of the Territory can experience up to 40 potential frost days a year; however, the actual occurrence of frost depends on factors including temperature, humidity and cloud cover.

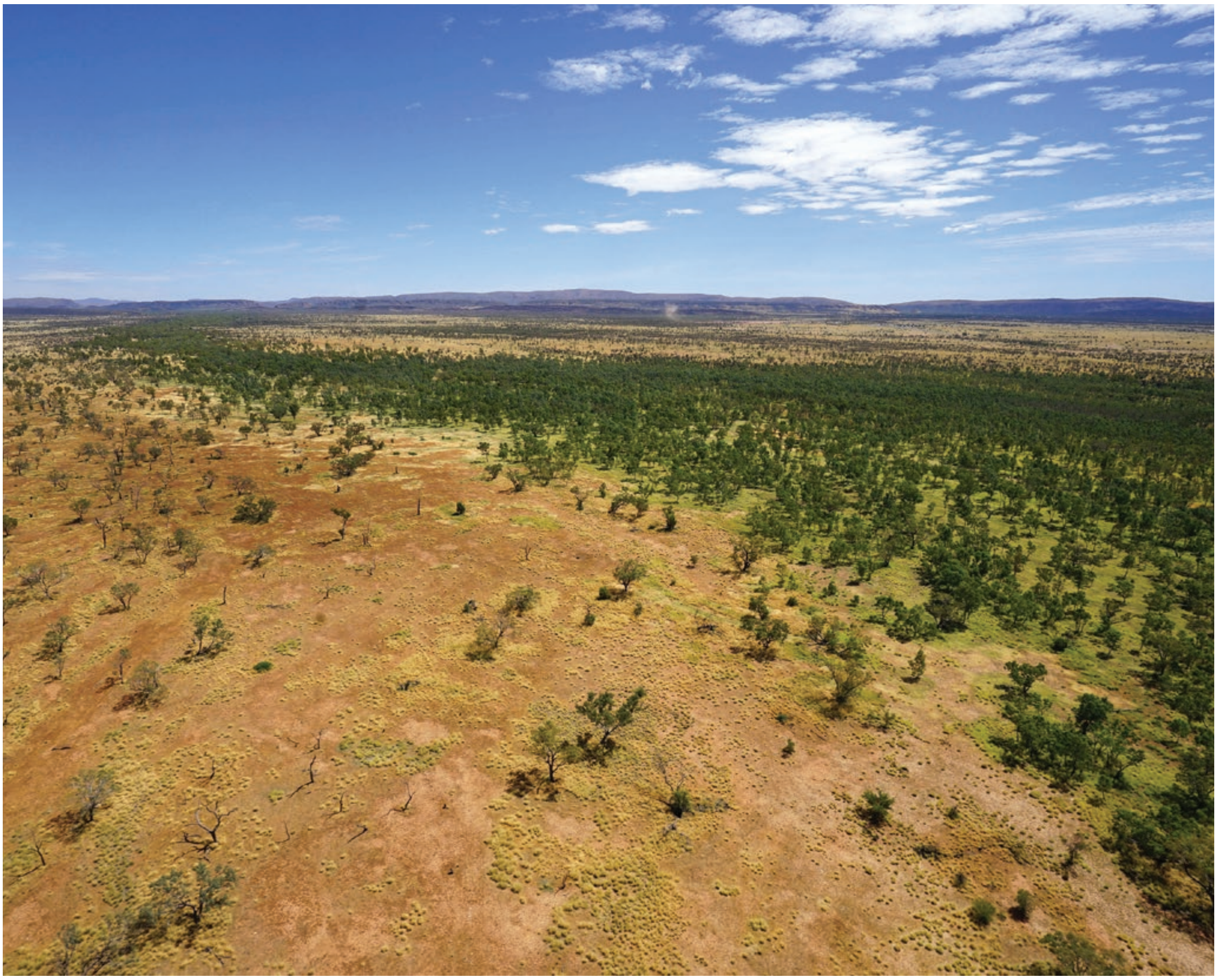
Frost risk days will decrease over time. For example, the number of frost risk days in Alice Springs will be halved by the middle of the century under the high emissions pathway.



Frost days will decrease.

Table 2.3. Projected annual number of days below 2°C.

ANNUAL DAYS BELOW 2°C	Historical (1981–2010)	2030 (2016–2045)		2050 (2036–2065)		2090 (2075–2104)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Alice Springs	31	24	21	19	16	13	4
Yulara	24	15	13	11	9	7	1



2.3 Rainfall

2.3.1 Average rainfall

The Territory's Top End receives 600–1800 mm of rain in the wet season, but only 100–400 mm in the dry season (Figure 2.8).

Rain falls all year around in the central and southern parts of the Territory, but winter is the driest season with an average 50–100 mm rainfall in the central part of the Territory and 100–200 mm in the south. In summer, average daily rainfall in the central region is 400–900 mm and 200–400 mm in the south.

Rainfall can vary a great deal from year to year due to the normal variability of the climate system (Figure 2.9)

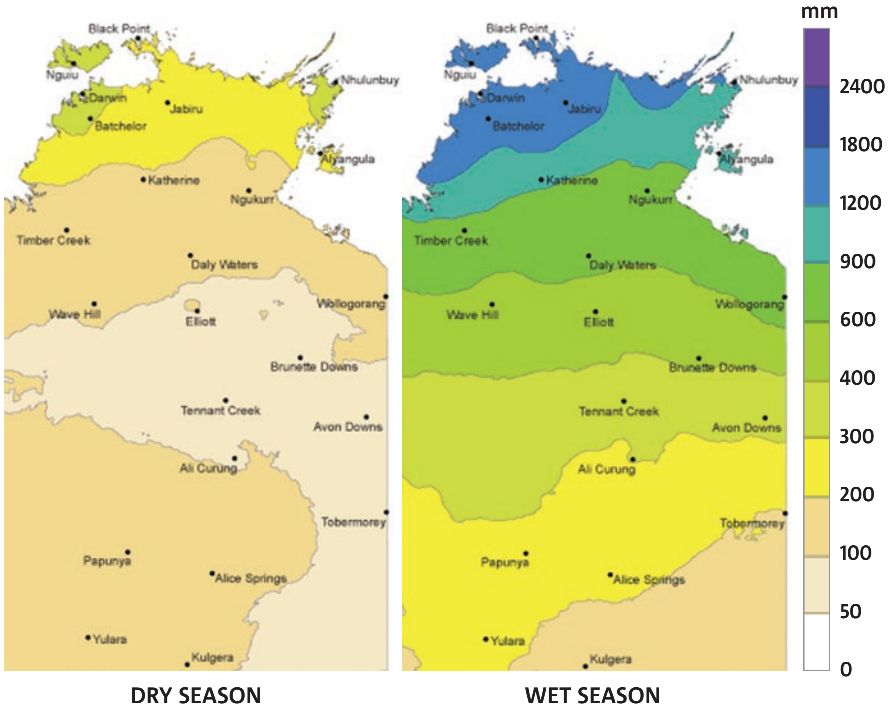


Figure 2.8. Average wet and dry season rainfall (mm) over the period 1961 to 1990
(Source: Bureau of Meteorology)

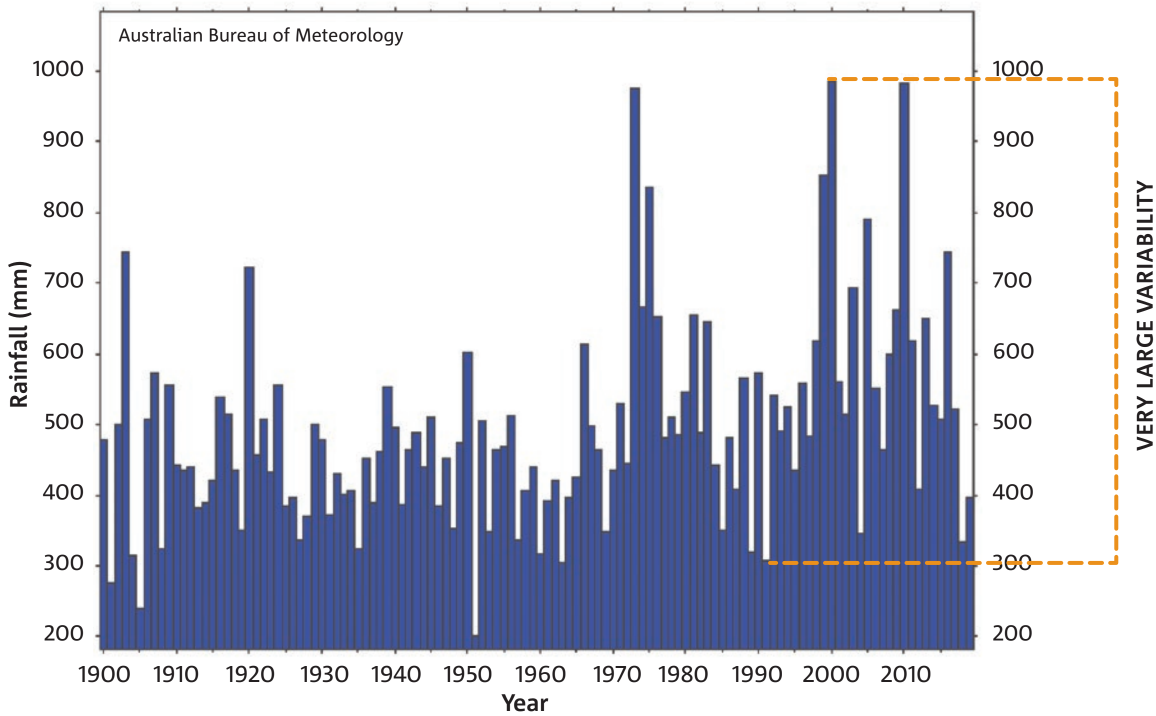


Figure 2.9. Total wet season rainfall (mm) for the period 1900/01 to 2019/20 showing the high year-to-year variability.

Over the past century, annual total rainfall has increased except for a small region in south-east Arnhem Land (Figure 2.10, left panel). More recently, drying in this region and further north on the coast has increased (Figure 2.10, right panel).

Comparing the 1959–1988 annual rainfall average with that for 1989–2018 indicates that annual rainfall has increased across the Northern Territory (Table 2.4).

There have also been changes in seasonal rainfall. Wet season rainfall has increased over the Top End, with Darwin recording a seasonal average of 1732 mm per annum for the period 1989–2018 compared to 1586 mm for the period 1959–1988 (BoM et al 2019a), and Tennant Creek recording an average of 459 mm and 343 mm per annum for the same periods, respectively (BoM et al 2019b). The annual average amount of rainfall at Alice Springs remained relatively unchanged between 1959–1988 and 1989–2018, although the seasonal distribution has changed, with more summer rainfall and less in March and the winter months (BoM et al 2019c).

In the near future, the effect of natural variability on rainfall is greater than the effect of climate change.

For the near future, natural variability will cause greater year-to-year changes in rainfall than the effects of climate change. In the Top End, near-future projections for the dry season range from 35% drier to 29% wetter than the 1986–2005 average, depending on greenhouse gas concentrations.

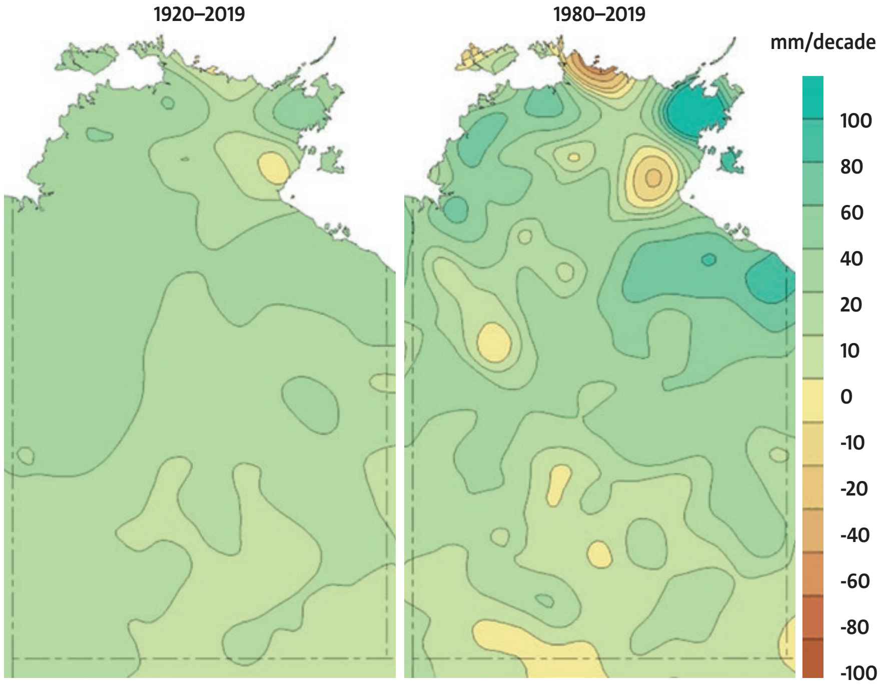
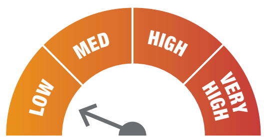


Figure 2.10. Long-term (1920–2019, left) and shorter-term (1980–2019, right) trends in annual total rainfall in the Northern Territory in mm per decade.

Projected wet season change for the same period ranges from 8% wetter to 7% drier. In the central and southern Northern Territory, annual rainfall change projections range from 12% drier to 8% wetter.



Later in the century, both wetter and drier futures are plausible depending on greenhouse gas concentrations.

Towards the end of the century, the projected dry season change in the Top End ranges from 45% drier to 44% wetter, depending on greenhouse gas concentrations. For the wet season, the range is 23% drier to 19% wetter. In the central and southern parts of the Territory, projected annual rainfall change ranges from 31% drier to 19% wetter, depending on greenhouse gas concentrations.

These large ranges and unclear direction mean that planning needs to consider both a drier and wetter future. A full table of projected changes in annual and seasonal average rainfall is included in the appendix.

How are we tracking?

The observed rainfall (dark line) has been tracking above the projected range, but within that expected from decadal variability, and has recently seen some drier years (Figure 2.11). The high variability makes it hard to assess if the projections are credible so far and we will need to wait for observations to 2030 to better assess the projection but so far, the observed trend is consistent with the projection.

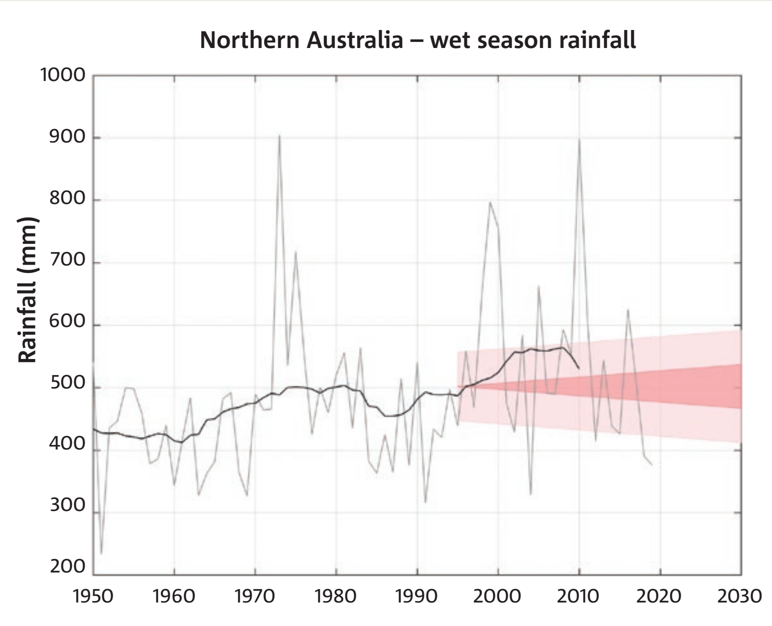
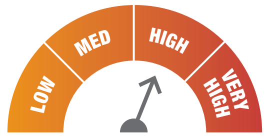


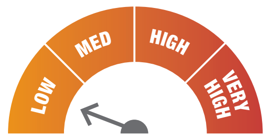
Figure 2.11. Total wet season rainfall in northern Australia as a whole (north of 26°S) for each year since 1950 (thin line) and the underlying trend (thick line) with the projected range of change for 1986–2005 to 2020–2039 under any emissions scenario from Climate Change in Australia added as a pink range. The decadal variability is shown as a feint pink band. (The trend uses a 20-year moving average (Hawkins et al. 2020), observations are from AWAP.)

2.3.2 Extreme rainfall

Extreme rainfall in the Northern Territory often results from tropical cyclones, tropical lows and long-lived thunderstorms.



Heavy rainfall events will become more intense.



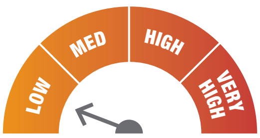
How much more intense is not clear.

As the air becomes warmer it has a greater capacity to hold water vapour. This means that, even though changes to average rainfall are unclear, the intensity of heavy rainfall events will likely increase in the future across the Territory.

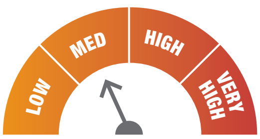
2.3.3 Drought

From the Federation Drought at the turn of the 20th century through to the recent 2017–2020 drought, Territorians have experienced a number of periods of extended, unusually dry conditions. Drought occurs all over the Territory; however, the south is typically more prone to drought than the north.

Impacts of drought are likely to be more severe in the future due to increasing temperatures. However, changes in drought are unclear in climate models, given the relationship to rainfall. We have low confidence in projecting how the frequency and duration of extreme meteorological drought may change, although under a high emissions pathway the time spent in drought will increase by 2090 in the central and southern parts of the Territory.



Frequency and intensity of droughts will change.



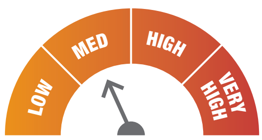
Time spent in drought will increase.

2.4 Tropical cyclones

Tropical cyclones can occur in the Northern Territory between November and April. The Northern Territory is in Australia's Northern tropical cyclone region, which covers the Territory and extends west to the north-eastern Kimberley and east to the Queensland Gulf coast. On average, there are three tropical cyclones each season in this region (BoM 2019).

Tropical cyclones contribute up to 12% of rainfall along the coastal region of the Territory during the tropical cyclone season (Dare et al. 2012). Contributions to inland rainfall get progressively smaller as you move further south. The frequency of tropical cyclones varies considerably from year to year due to the influence of large-scale climate drivers (see Section 2.2).

The number of tropical cyclones across the Australian region has been declining since formal records began; however, over the Northern Territory there has been no discernible trend (Chand et al. 2019).



Tropical cyclones will become less frequent but more intense.

Tropical cyclones are projected to become less frequent but with more energy in the climate system from warming, they are likely to be more intense.

There is some potential that tropical cyclones may also reach slightly further south under a warmer climate, associated with warmer oceans and changing large-scale wind patterns. However, there is relatively low confidence in regional aspects of these projections due to challenges associated with modelling tropical cyclones, including their frequency, intensity, formation and tracks (ESCC Hub 2019a).

Rainfall produced by tropical cyclones is also expected to increase, particularly the intensity of extreme rainfall events which could increase by about 10% or more per degree of global warming (noting that about one degree of warming has already occurred). This is because a warmer atmosphere can hold more moisture, as well as increase the energy available for cyclones (ESCC Hub 2019a).

When this increased rainfall intensity is combined with higher sea levels (see Section 4.7.1), it is likely that flooding will increase in frequency and magnitude in the future for many coastal and estuarine regions.

2.5 Fire weather

Bushfire occurrence relies on having an ignition source, fuel availability, fuel dryness and suitable fire weather (hot, dry, windy). In the Northern Territory fuel availability is a major limiting factor. This depends largely on rainfall.

In the central and southern regions of the Territory, conditions are most conducive to bushfires in spring (September–November). In the north, the most dangerous fire weather conditions occur in the dry season. This is when conditions are drier and there is increased fuel availability following the wet season. Over the past 30 years or so, the number of days with severe fire weather has increased during the dry season (winter and spring) (ESCC Hub 2019b; Figure 2.12).

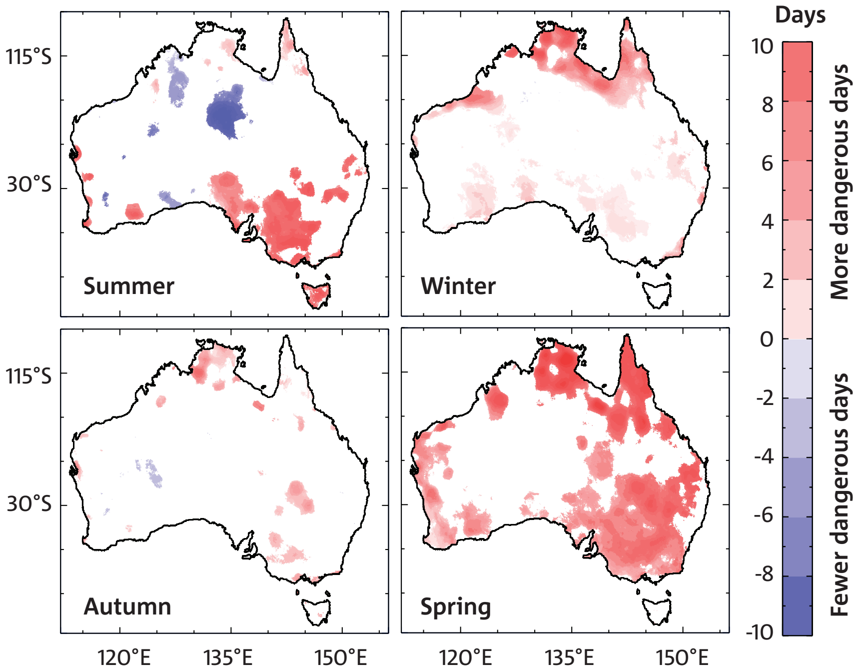
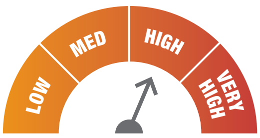


Figure 2.12. The number of fire weather days in the period 2000–2016 compared with 1983–1999. Dangerous days are those where the Forest Fire Danger Index (FFDI) is greater than the 90th percentile at a given location. (Source: ESCC 2019b)



Fire weather will become more frequent and harsher.

In the Top End, where abundant rainfall and bushfires are common, there is projected to be little change to fire frequency.

In the southern and central parts of the Territory, changes to fire frequency depend on rainfall changes. With higher temperatures and lower rainfall, climate change will result in a harsher fire-weather climate in the future; that is, when bushfires occur, more extreme fire behaviour can be expected.

The national projections for fire weather are based on a Forest Fire Danger Index. Given the relatively low proportion of forested areas in the Northern Territory, this measure is not as accurate as in other states but can still be used as a useful indicator of possible fire weather changes.

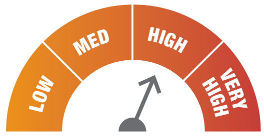
2.6 Evaporation

While evaporation rates have largely remained unchanged in the Top End (BoM et al. 2019a), in the central part of the Territory they have decreased. At Tennant Creek over the past 30 years (1989–2018) there has been a decrease in potential evaporation of about 5–10 mm in each of the cooler months (June through August), and of more than 20 mm in the warmer months compared with the previous 30 years (1959–1988) (BoM et al. 2019b). In the southern part of the Territory, spring and autumn potential evaporation rates at Alice Springs have increased by 10–20 mm for each month in the past 30 years (1989–2018) when compared to the previous 30 years (1959–1988). In other months, potential evaporation has increased by less than 10 mm each month (BoM et al. 2019c). Understanding changes in evaporation is important for planning how much water our agricultural industries will need.

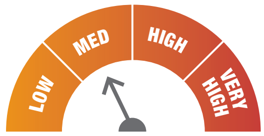
Estimating evaporation

Measures of evaporation may use one or more of a number of terms to describe what is being measured. Actual evaporation is difficult to measure, so potential evaporation is generally used instead. Potential evaporation is the maximum possible evaporation rate under given meteorological conditions if water is available. Measuring potential evaporation over a large region is not practical, so it is estimated by pan evaporation, which is a measure of potential evaporation over a small body of open water (like a pool or 'pan').

The terms evaporation and evapotranspiration are also used, sometimes interchangeably; however, evaporation refers to the transfer of water from the land surface to the atmosphere while evapotranspiration also includes transfer via vegetation.



Potential evaporation will increase.



The size of the increase is less clear.

Across the Territory projections for potential evapotranspiration indicate increases in all seasons, with the largest absolute rates in summer by 2090.

A full table of projected changes in annual and seasonal average evapotranspiration is included in the appendix.

2.7 Humidity

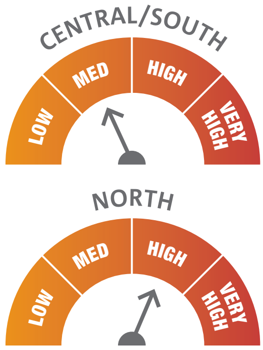
Relative humidity is the amount of moisture in the air as a percentage of the total amount of moisture the air can hold. For example, 50% relative humidity means the air is holding half the moisture it could possibly hold. Relative humidity depends on temperature: cooler air does not hold as much moisture as warmer air. This means that for any specific amount of moisture, the relative humidity will be higher at cooler temperatures – which is why Alice Springs has high relative humidity in winter months (Figure 2.13).

In the near future there is little change projected in relative humidity across the Territory.

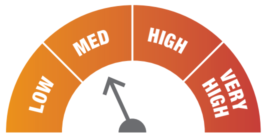
By the end of the century, under a high emissions pathway, relative humidity is projected to decrease in the Top End.

In the central and southern parts of the Territory a decrease in relative humidity is projected in summer and autumn. Projections for a decrease in winter and spring (up to 5% under medium emissions and 10% under high emissions) have high confidence.

A full table of projected changes in annual and seasonal average relative humidity is included in the appendix.



In the near future we expect little change in relative humidity across the Territory.



At the end of the century, relative humidity will decrease across the Territory.

Along with temperature and wind speed, relative humidity determines how cold or hot it actually feels. This is often reported as 'apparent' or 'feels like' temperature - although in the NT it could be called 'How sticky is it today?'

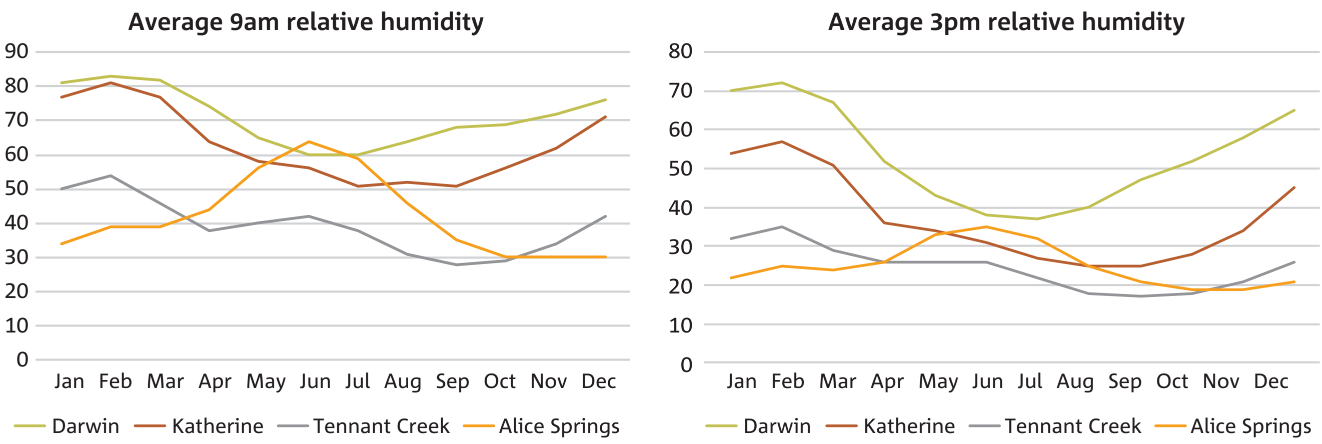


Figure 2.13. Average monthly relative humidity at 9 am (left) and 3 pm (right) for Darwin (Darwin Airport, station 014015; 1954–2010), Katherine (Katherine Council, station 014902; 1957–2010 9 am, 1957–1985 3 pm), Tennant Creek (Tennant Creek Airport, station 015135; 1969–2010) and Alice Springs (Alice Springs Airport, station 015590; 1954–2014). Data from Bureau of Meteorology.

2.8 Coasts and oceans

2.8.1 Mean sea level

Global warming is causing sea levels to rise in two ways. The first is through thermal expansion – as water warms, its volume increases (so it takes up more space). This accounts for around one-third of the rise we have seen to date (CSIRO and BoM 2018). The remainder is from melting ice sheets and glaciers that are adding more water to the oceans.

Melting ice and snow on land increase sea level because this adds water to the oceans, but melting sea ice does not increase sea level because it's water already in the ocean. It's just the same as when ice floating in your drink doesn't cause it to overflow as it melts in the Territory heat!

Sea levels have risen around Australia

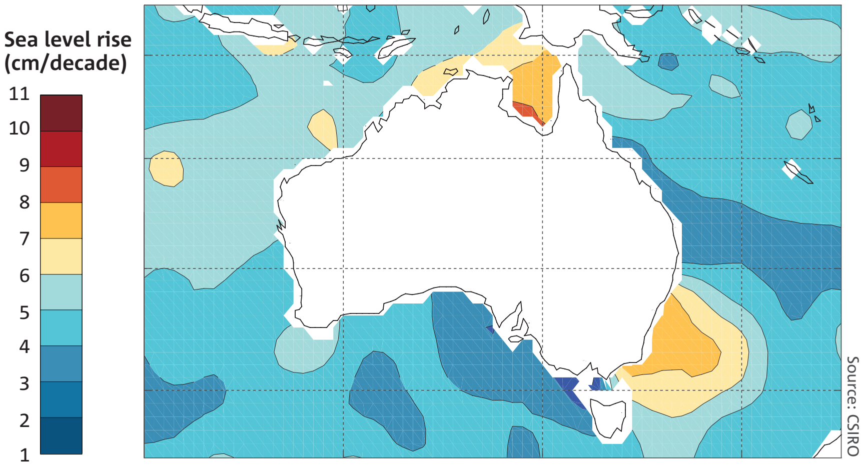
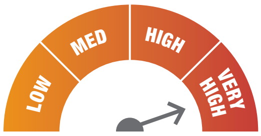


Figure 2.14. The rate of sea-level rise around Australia based on satellite observations for 1993–2017. (Source: CSIRO and BoM 2018)

Sea level rise is not uniform. Changes occur at many time scales (from hours to decades) due to factors including tides, storm surges, seasonal changes and the influence of climate drivers like El Niño and La Niña (CSIRO 2020).

The sea level around the Northern Territory coastline has risen at a higher rate than much of the rest of the country due to the combination of natural climate variability and climate change (White et al. 2014) (see Figure 2.14).

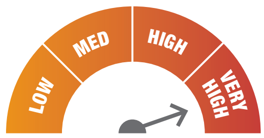


Mean sea level will continue to rise.

In the near future, the projected increase is 0.06 to 0.17 m above the 1986–2005 level, with only minor differences between the different emissions pathways. As the century progresses, the differences between the pathways become more pronounced. At the end of the century, a medium emissions pathway gives a rise of 0.28 to 0.64 m while a high emissions pathway gives a rise of 0.38 to 0.85 m (Figure 12.15).

2.8.2 Extreme sea level events

Tides, winds and severe weather systems can cause extreme sea-level events. In the Northern Territory, tropical cyclones cause extreme storm surges.



The height of extreme sea levels will increase.

Rising sea levels will exacerbate the impacts of storm surges and other extreme sea-level events.

Projected sea-level rise under a high emissions pathway for coastal local government areas

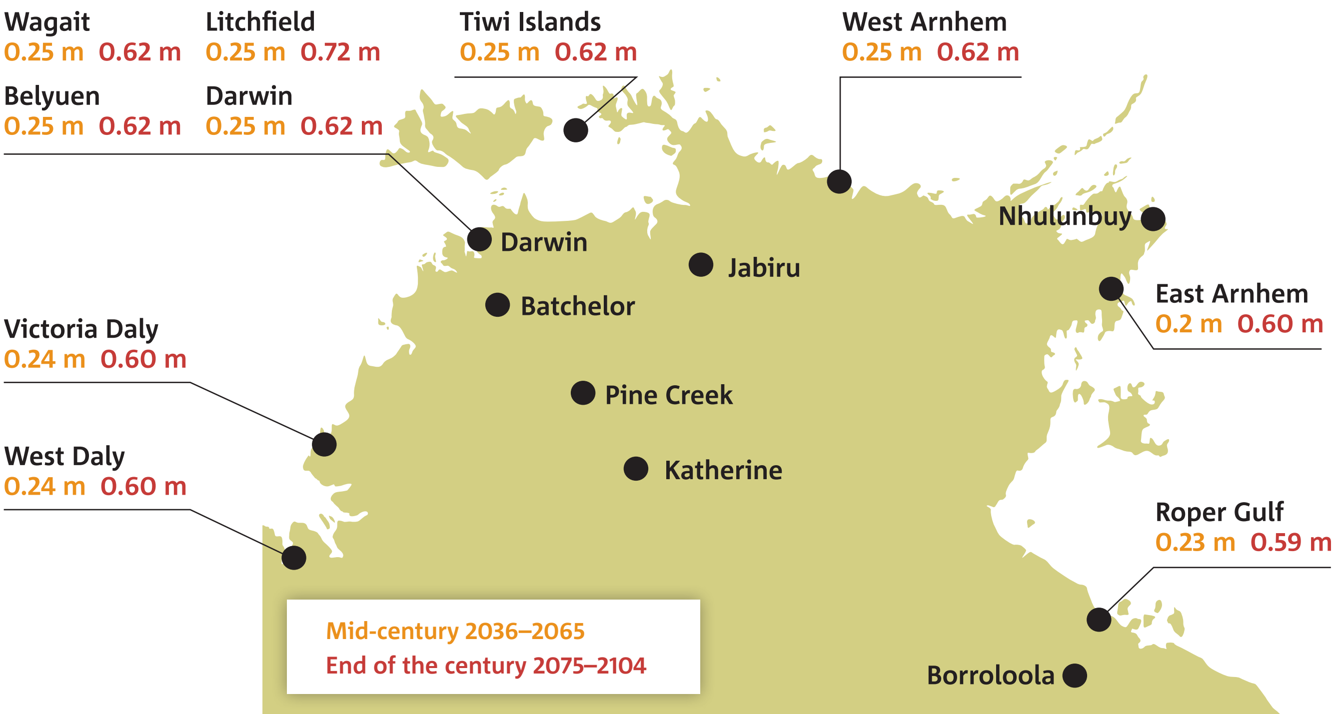
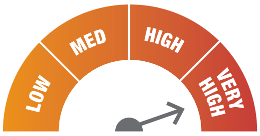


Figure 2.15. Mean projected sea-level rise for the middle (2050, orange) and end of the century (2090, red) for Northern Territory coastal local government areas under a high-emissions (RCP8.5) pathway.

A full table of sea-level rise projections for Northern Territory coastal local government areas is included in the appendix. The table also includes allowances, which are the minimum distances required to raise an asset to maintain current frequency of breaches under projected sea-level rise.

2.8.3 Sea surface temperature

Sea surface temperature has risen significantly across the globe over recent decades. Sea surface temperature around the Northern Territory has warmed by at least 0.5°C since 1950 (Figure 12.16).



Sea surface temperature will continue to increase.

In the near future, sea surface temperature at Darwin is projected to increase by 0.4 to 1.1°C. At the end of the century warming across the Northern Territory's coastal waters is projected to be from 0.3 to 1.6°C under a low emissions pathway up to 2.2 to 4.1°C under a high emissions pathway.

2.8.4 Marine heatwaves

In the same way that heatwaves are extended periods of high temperature on land, extended periods of high sea surface temperatures are known as marine heatwaves.

Globally, marine heatwaves are becoming longer and more frequent: between 1925–1954 and 1987–2016 the number of marine heatwave days averaged across all the oceans increased by 50%. They are also becoming more intense (Oliver et al. 2018a).

The 2015/16 northern Australian marine heatwave persisted for 224 days – the longest in the region on the satellite record – with the temperature rising to 1.6°C above average. The changing climate has been shown to have increased the likelihood of this event occurring (Oliver et al. 2018b).

The number and intensity of marine heatwave days will increase.

The number of marine heatwave days per year and the intensity of marine heatwaves is projected to increase across the 21st century, with the degree dependent on greenhouse gas emissions. Under a high emissions pathway, the intensity of marine heatwaves could be double that of under a medium emissions pathway (Oliver et al. 2019).

2.8.5 Ocean chemistry

Around one-third of the carbon dioxide emitted into the atmosphere by humans over the past 200 years has been absorbed by the oceans. This has led to a 0.1 pH fall in the ocean's surface water pH (a 26% rise in acidity).

The ocean surface around Australia has warmed, especially to the southeast

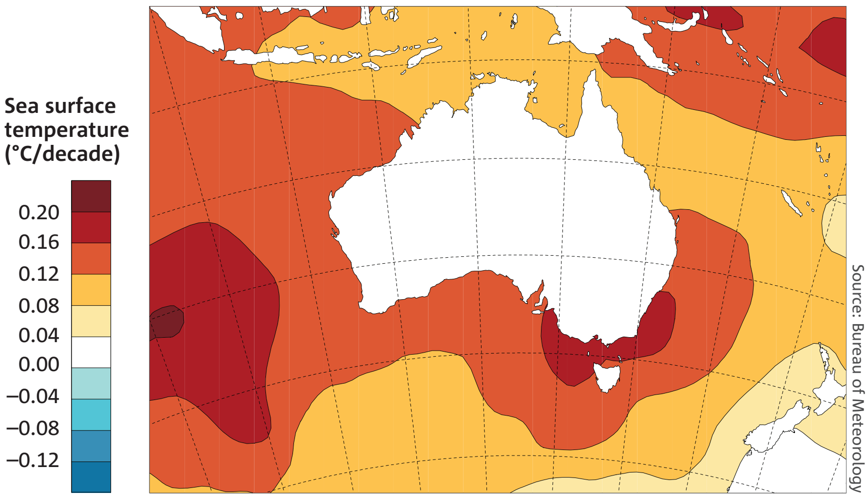
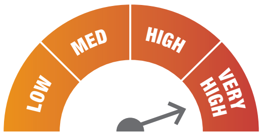


Figure 12.16. Trends in sea surface temperatures in the Australian region from 1950 to 2017. (Source: CSIRO and BoM 2018)



The ocean around Australia will become more acidic at a rate proportional to carbon dioxide concentrations in the atmosphere.

In the near future, pH is projected to fall by an additional 0.07 units in the Northern Territory's coastal waters. At the end of the century, decreases of up to 0.14 (under medium emissions) and 0.3 (under high emissions) are projected. These values represent a 40 and 100% increase in acidity respectively.

pH

Acidity is measured using the pH scale, which ranges from 0 to 14, where 0 is most acidic and 14 is most alkaline (or basic). A pH of 7 is neutral. The scale is logarithmic which means each whole number value below 7 is 10 times more acidic than the previous value. This is why small changes in pH (e.g. 0.1) are big changes in acidity (26%).

3. Impacts on the Territory

Our environment, communities and economy are all vulnerable to the changing climate. Many aspects of Territory life are already being impacted. Identifying and understanding these impacts is critical for planning for the future – to reduce the risk of ongoing or more severe impacts and to identify opportunities for Territorians to build more resilient communities, develop a sustainable economy and maintain healthy natural systems.

3.1 Community/ environment

3.1.1 Human health

Climate change will have both direct impacts on human health as well as other impacts that may not be immediately recognised. Some groups are likely to be more susceptible to climate change, such as young children, older people, people with existing chronic illnesses, the socially isolated or disadvantaged, outdoor/ manual workers, very low-income workers, women seeking shelter, people in communities dependent on agriculture and land and Aboriginal Territorians (Coast Adapt 2017).

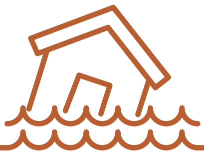
- Extreme weather events could result in injuries and death.
- Increased temperatures and extreme heat days will result in heat stress and dehydration.
- Heat stress can exacerbate cardiovascular, renal and other chronic diseases.
- Floods (and humidity) favour vector-borne diseases (malaria, dengue, other fevers), melioidosis, leptospirosis which can result in death.
- Displacement of livelihoods could lead to stress, anxiety and other mental health problems.
- Bushfire smoke could lead to respiratory problems.
- Extreme weather and flooding can disrupt transport networks, impacting on food availability and security, as well as provision of health and support services.

Treatment of kidney disease

The best treatment option available for patients with advanced kidney disease is haemodialysis. It can be accessed at home or in communities, but it requires a reliable and high-quality water supply. Each dialysis treatment requires 600 litres of water and patients dialyse three times per week for up to seven years. An estimated 31.1 megalitres of water was required in both the Top End and Central Australia for haemodialysis treatments in 2018–19. Projections indicate that haemodialysis water use will more than double to 81.5 megalitres by 2036. Water scarcity is likely to force the majority of clients to undergo their treatment in major urban settings, reducing their ability to have community-based dialysis, dislocating them from their land and culture, and potentially increasing urban water security challenges.

3.1.2 Coasts and marine resources

The vulnerability of our coastal areas to sea level rise is influenced by a variety of factors such as human activities, nature of coastal processes, geographic location, and type of land cover. The impacts of sea level rise will be felt most acutely from the combination of extreme events – such as high tides, surface waves, storm surge and flooding rivers – which are becoming more intense and frequent (Pathirana and Baban 2008).



- Rising sea levels and storm surges will impact coastal communities and infrastructure (roads, jetties, marinas, landings and boat ramps as well as homelands and outstations), cultural artefacts and sacred sites, and has the potential to contaminate groundwater sources.
- Flooding compromises infrastructure (i.e. residential and commercial structures, public infrastructure) from pressure forces and floodwater.
- Building materials may decay after contact with floodwaters which are accelerated from contaminants (e.g. sewage, petrol and chemicals).
- Floating debris can also cause additional damage or pressure, and the force of floodwaters can cause erosion and collapse of soils supporting a structure (Mason et al 2010; NCCARF 2016).
- Infrastructure such as roads, culverts and bridges can be severely impacted by floodwaters.
- Erosion can undermine foundations and impact infrastructure in close proximity to coastal and estuarine foreshores (NCCARF 2016; Woodroffe et al 2010).

Seagrass

Rising water levels mean that seagrass will get less light and intertidal meadows will have more exposure to daylight during low tides. This will reduce the area they can survive in, which will in turn affect the number of dugongs, as they rely solely on seagrass for food. This will reduce the number of dugongs in our waters, and impact on cultural and resources values for Aboriginal communities across the Top End.

3.1.3 Water supply

Climate change impacts rainfall, underground water reserves, surface water flows, and changes how humans use water. How these impacts play out across the Territory will be region and ecosystem specific and cannot be generalised for the whole of the Northern Territory.

- Water supply and quality can be affected by damage and disruptions in long-lived constructed civil, mechanical and electrical assets such as dams, pipelines, treatment plants and pumping stations.
- Higher intensity rainfall events will test the capacity of stormwater systems, treatment plants and sewerage networks.
- Extended periods of hot, dry weather can lead to pipes cracking as a result of changes in soil moisture or temperature, or as tree roots spread to source water.
- Sea level rise, storm surge and flooding are likely to affect water and wastewater infrastructure and can result in water contamination issues which impact public health and the environment (National Water Commission 2012; Infrastructure Australia 2017, 2019).

3.1.4 Biodiversity and ecosystems

The identity and lifestyle of most Territorians are integrated with the Territory's biodiversity and ecosystems through both employment and leisure. For Aboriginal people, who managed and originally shaped this landscape, connections with the natural world are deeply spiritual, and reflected in an intricate belief system with resounding expression in ancient art forms. We want to ensure that the biological diversity and integrity of the Territory's natural heritage remains intact both now and for future generations.

The way that climate change impacts the natural environment of the Northern Territory will vary between regions, ecosystems and species.

- Rising temperatures and sea levels, as well as climate-induced changes in fire regimes, and extreme weather events will intensify existing threats such as habitat loss, invasive species and drought.
- Marine heatwaves can cause coral bleaching, which can damage the integrity of reefs and reef ecosystems.
- Increasing sea and air temperatures could change species ranges and timing of life cycle stages.

Gulf of Carpentaria mangroves

Climate change is likely to damage key natural systems, as evidenced by the mangrove dieback in late 2015 in the Gulf of Carpentaria. The coincidence of unusually hot and dry conditions with unusually low sea level likely provided a stressful environment for the mangroves. This cumulative stress during most of 2015 almost certainly contributed to the major dieback near the end of the year (Harris et al. 2017)

3.2 Economic sectors/assets

3.2.1 Agribusiness

Agribusiness encompasses all forms of agriculture undertaken in the Northern Territory including the production of all types of livestock, crops, seafood (wild caught and/or farmed) and bush foods (collected and sold on a commercial basis).

In 2017-18, agribusiness contributed approximately 2.8% (or $735 million) to the Northern Territory's GSP and employed an estimated 4.1% of the Northern Territory workforce (or 1743 jobs).

Disruption to the agribusiness sector will have a flow-on impact to Territory-based suppliers supporting the sector – including specialist heavy vehicle transport providers and businesses providing the inputs such as agrichemicals, farm machinery, fencing, irrigation equipment and seeds.

- Current breeds may not tolerate the changes in climate such as an increase in extreme heat days.
- Heat stress could decrease productivity through reduced feed intake.
- Increased temperatures lead to higher water demand by grazing animals and this tends to lower the range from which the animals will travel from their water source. This limits the use of the available grazing resources and increases the pressure placed on pastures adjacent to water sources and lifts the risk of soil degradation.
- Increased variability of the Top End's wet season will periodically reduce the level of feed available for cattle and increase the potential for bushfires to further reduce the available pasture as well as cause additional damage to fences and other infrastructure.
- Variability in weather and rainfall can be expected to cause changes to the risks associated with pests and diseases and thereby potentially increase the cost to manage these impacts.
- Extreme weather and flooding can disrupt transport networks, making access to markets, supplies and workforce difficult.

- A drier climate with more intense rainfall events increases risks from runoff leading to erosion and loss of topsoil.
- Current varieties may not tolerate the changes in climate such as an increase in extreme heat days.
- Exposure to increases in the length and severity of heat waves and an increase in the number and severity of extreme weather events may impact on horticultural production in the Territory.
- Variability in weather and rainfall can be expected to cause changes to the risks associated with pests and diseases and thereby potentially increase the cost of inputs.
- Forestry plantations on the Tiwi Islands and in the Douglas Daly region are likely to be at greater risk of fire damage.
- Sea level rise can lead to increased saltwater intrusion and tree dieback in coastal and floodplain properties and potential changes to aquifer water quality.
- Extreme weather and flooding can disrupt transport networks, making access to markets, supplies and workforce difficult.

- Rising sea temperatures and sea levels may change fish and prawn distribution and abundance and the range of coastal areas available for aquaculture.
- With more variability in the reliability of the Top End's wet season, reduced run-off in the creeks and rivers in some years is expected to impact on the availability of key fish species.
- Variability in weather and rainfall can be expected to cause changes to the risks associated with pests and diseases and thereby potentially increase the cost of inputs.
- Extreme weather and flooding can disrupt transport networks, making access to markets, supplies and workforce difficult.

Mango production

Mango production is sensitive to temperature change as flowering is promoted by low night temperatures and can be inhibited by high day time temperatures. In the future, some commercially important varieties may no longer be suitable for where they are currently growing. Mango growers will need to consider a range of adaptation options to ensure the ongoing sustainability of their businesses (Clonan et al. 2020).

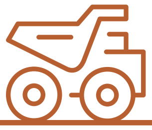
3.2.2 Infrastructure (construction)

The Northern Territory's construction industry employs more than 10,000 people – 7.8% of the Territory's workforce. In 2018–19, the industry contributed $1.6 billion to the Northern Territory economy (Northern Territory Government n.d.).

- Climate change will significantly impact infrastructure in multiple direct and indirect ways. The vulnerability of infrastructure is determined by the degree of climate change to which it is exposed and also how we respond in the design of our infrastructure: how and where we build new structures; how we adapt existing ones and how we modify our infrastructure use (The Climate Institute 2012).
- Direct physical risks include weather or temperature related events such as floods, rising sea levels and more intense natural disasters.
- Indirect risks to infrastructure from climate change include the changes in financial systems, for example, the availability of funding and insurance for infrastructure projects and the behavioural changes brought about by adapting to climate change.
- In the construction industry, climate change may change access to worksites, conditions for workers, and building standards.

4.2.3 Energy and minerals

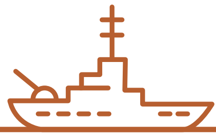
The mining, manufacturing and energy sectors (including natural gas and LNG) accounted for 22.7% (or $5.74 billion) of economic output and employed approximately 5.2% of the Northern Territory workforce in 2018-19 (Northern Territory Government n.d.).



- More frequent and intense natural disasters can damage mines, transportation and energy infrastructure and equipment. The damage caused may in turn disrupt construction and operations.
- Heavy rain and increased erosion may affect slope stability for open-cut mines and their related mullock heaps.
- Flooding from increased rainfall in some areas can interrupt production and may necessitate additional controls to enhance water treatment capacity.
- Heavy rainfall is likely to disrupt land transportation routes and degrade roads.
- Increasing temperatures, greater precipitation, shifting storm patterns, and rising sea level may impact the transportation services that supply goods and services, carry personnel and move ore to facilities for processing and to ports for export.
- Disruption in delivery of input materials or consumables such as diesel, tyres, and reagents, will curtail production or limit its efficiency.
- Rising sea level may make coastal facilities harder to access and major cyclones will affect port availability, interfering with timely transport to market.
- Hotter and drier conditions may increase wildfires that threaten facilities.
- Increased water scarcity in some locations will inhibit water-dependent operations and complicate site rehabilitation.
- Heavier rainfall could result in tailings dam failure, discharge of contaminated water into surrounding areas, accompanying remediation costs and increases in environmental liability.
- Natural disasters pose immediate health and safety risks, while warmer temperatures may affect worker recruitment, retention, safety and productivity.

3.2.4 Defence and defence support initiatives

The Northern Territory is strategically important for the Australian Defence Force (ADF) and this is reflected in the key role the ADF plays in the Northern Territory economy. The ADF contributes approximately $1.9 billion to the Northern Territory economy annually through direct and indirect employment of Territorians, demand for goods and services, exercises held and infrastructure projects. There are approximately 12,000 ADF personnel and their families based in the Northern Territory, which is 8.1% of the ADF population.



- Increases in heatwaves and heat stress in the wet season may limit outdoor activities by ADF personnel.
- General climate change impacts could contribute to an increase in political and military conflict in Asia which could impact northern Australia, resulting in internal and external migrations in the region and the need for additional infrastructure and industrial capacity to support the Australian Defence Force and its visiting forces.

Disaster and humanitarian support

The Northern Territory is one of the key deployment points for disaster and humanitarian assistance in the region with the National Critical Care and Trauma Response Centre located in Darwin. The Australian Defence Force has been deployed from the Territory on several occasions to provide logistical, environmental and medical support. As multiple disaster events increase in severity and frequency, there will be increasing pressure on the Northern Territory's existing capacity to appropriately respond to these events.

3.2.5 Tourism

The Northern Territory's tourism is driven in part by some of Australia's most iconic nature-based tourist attractions, including Garig Gunak Barlu (Cobourg) National Park, Litchfield National Park, Uluru-Kata Tjuta National Park and Kakadu National Park.

In 2018–19, tourism directly contributed $1.4 billion to the Northern Territory economy. In this period, the sector directly employed nearly 8,500 people but with indirect employment figures this rises to around 15,500 people (Northern Territory Government n.d.).

- Rising temperatures and more extreme heat days can increase heat stress and loss of human life.
- Extreme weather and subsequent flash flooding can increase risks for visitors who are unfamiliar with the local environment and driving conditions.
- Flood and fire can damage infrastructure (including utilities and roads), the environment and ecotourism resources (e.g. wetlands, wildlife habitats and other natural attractions)
- Damage and disruption caused by climate-related events can result in a loss of tourism revenue and jobs.
- Extreme weather and flooding can disrupt transport networks, inhibiting travel within the NT and access to national parks and other popular tourist sites.
- The late retreat of the monsoon in the Top End can shorten the visitor season due to extended seasonal closures. This impacts employment, revenue flows and profitability for the industry. Extended seasonal closures can heavily erode visitor satisfaction with the destination more generally and can negatively affect the intention to travel among potential visitors in the future.
- Key natural systems can be damaged through prolonged or unusual climate events, threatening the viability of marine ecosystems and populations of species such as crocodiles and turtles which are a drawcard for tourism.

Kakadu wetlands

As well as impacts that disrupt access and visitor comfort, climate change could have significant impact on the Territory's natural tourist drawcards. Sea-level rise of 30 cm could cause the loss of 80 per cent of the area of Kakadu's freshwater wetlands (CSIRO 2014), potentially affecting visitation to the area.

4. Responding to change

Territorians need to actively respond to the changing climate in order to maintain sustainable and resilient communities, a healthy environment and a strong economy. Broadly, responding to climate change involves reducing greenhouse gas emissions to limit further change and doing things differently to manage the change that is unavoidable. Individuals, communities, industries and government all have a part to play.

4.1 Mitigation: limiting further change

In order to limit the extent and consequent impacts of climate change, we need to minimise the increases of greenhouse gases in the atmosphere. This can be achieved by reducing emissions and by actively removing gases from the atmosphere by natural or engineered means.

It is important to note that reducing emissions will not immediately halt warming and reduce climate change. Just as a road train suddenly applying the brakes will take some distance to come to a complete stop, global warming resulting from past and current emissions will continue for a long time (decades to centuries).

The Paris Agreement

At the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change in Paris, 195 nations agreed to keep global warming below 2°C above pre-industrial levels, and to actively pursue a target of 1.5°C above pre-industrial levels.

Global warming reached 1°C above pre-industrial levels in 2017, and some regions have already experienced 1.5°C warming (IPCC 2018). Reducing emissions is essential if we are to limit warming to 2°C.

4.2 Adaptation: managing unavoidable change

Maintaining healthy communities, ecosystems and businesses in the face of a changing climate will require changes to how we currently do things. The climate impacts we are already experiencing, and those that are still to come, threaten to cause significant disruption unless we plan ahead and adapt to the changes that we are facing.

Individuals, communities, industries and governments all have a role to play in adapting to climate change. Responses range from practical actions at an individual level (e.g. a primary producer building a shade structure for their livestock) to policy responses at national and global levels.

4.3 What can I do?

Everyone has a part to play in the Territory's response to climate change – individuals, businesses and communities can all take actions to reduce emissions in an effort to limit continuing climate change, and to prepare for the changes that we are already locked into. These actions may include:

- Learning more about what causes climate change and how it will impact you. Reading this report is a great start – so well done!
- Making decisions to reduce your personal environmental footprint, for example by choosing green energy options or recycling and re-using instead of relying on single-use resources. A lot of individual actions by many individuals adds up to a big impact!
- Understanding the climate risks to your community or business and putting plans in place now to either avoid or respond to those risks. Climate change is not something that might or will happen in the future – it's happening now, so the sooner you take action, the better off you'll be!

For more ideas and information visit **https://climatechange.nt.gov.au**

4.4 Find out more

There are many places to find the latest, credible, science-based information about our changing climate. These include:

- National Environmental Science Program Earth Systems and Climate Change Hub – **http://nespclimate.com.au**
- Climate Change in Australia (Australia's national climate change projections) – **https://www.climatechangeinaustralia.gov.au**
- CSIRO – **https://www.csiro.au/en/Research/Climate**
- Bureau of Meteorology – **http://www.bom.gov.au/climate/change/**
- ARC Centre of Excellence for Climate Extremes – **https://climateextremes.org.au**

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APPENDIX:
PROJECTIONS SUMMARY DATA TABLES

Table A1. Change in mean, minimum and maximum temperature (°C) relative to 1995 (1986–2005). Median value is shown with 10th to 90th percentile range.

	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	**RCP4.5**	**RCP8.5**	**RCP2.6**	**RCP4.5**	**RCP8.5**	**RCP2.6**	**RCP4.5**	**RCP8.5**
MONSOONAL NORTH (WEST)									
Annual									
Mean	0.8 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.6)	1.3 (1.0 to 1.8)	1.8 (1.4 to 2.4)	1.0 (0.6 to 1.8)	1.8 (1.3 to 2.8)	3.7 (2.8 to 5.1)
Min	0.7 (0.5 to 1.2)	0.9 (0.6 to 1.3)	1.1 (0.7 to 1.4)	0.9 (0.7 to 1.5)	1.3 (1.0 to 1.8)	1.9 (1.4 to 2.4)	1.0 (0.6 to 1.7)	1.9 (1.3 to 2.7)	3.8 (3.1 to 5.2)
Max	0.8 (0.5 to 1.3)	0.9 (0.5 to 1.3)	1.0 (0.7 to 1.4)	1.1 (0.7 to 1.7)	1.3 (0.9 to 1.9)	1.9 (1.3 to 2.5)	1.0 (0.6 to 2.1)	1.8 (1.3 to 2.9)	3.6 (2.7 to 5.2)
Wet (November–April)									
Mean	0.7 (0.5 to 1.2)	0.8 (0.5 to 1.2)	0.9 (0.7 to 1.4)	1.0 (0.7 to 1.6)	1.3 (0.5 to 2.1)	1.8 (1.0 to 2.8)	0.9 (0.5 to 1.8)	1.7 (1.1 to 2.6)	3.3 (2.4 to 5.1)
Min	0.7 (0.5 to 1.1)	0.9 (0.6 to 1.2)	0.9 (0.7 to 1.3)	0.9 (0.7 to 1.5)	1.3 (0.7 to 1.9)	1.9 (1.0 to 2.6)	0.9 (0.6 to 1.6)	1.8 (1.2 to 2.7)	3.6 (2.7 to 5.0)
Max	0.8 (0.5 to 1.4)	0.9 (0.4 to 1.3)	0.9 (0.7 to 1.3)	1.1 (0.6 to 1.8)	1.4 (0.3 to 2.3)	1.8 (0.6 to 3.0)	1.1 (0.5 to 2.1)	1.8 (1.1 to 2.9)	3.4 (2.3 to 5.3)
Dry (May–October)									
Mean	0.9 (0.5 to 1.3)	1.0 (0.7 to 1.4)	1.0 (0.7 to 1.4)	0.9 (0.8 to 1.6)	1.5 (0.7 to 2.3)	1.9 (1.1 to 2.7)	1.0 (0.6 to 1.8)	2.0 (1.4 to 2.8)	4.0 (3.2 to 5.2)
Min	0.7 (0.4 to 1.2)	1.0 (0.6 to 1.2)	1.1 (0.8 to 1.5)	0.9 (0.6 to 1.6)	1.4 (0.7 to 2.3)	1.9 (1.2 to 2.8)	1.0 (0.5 to 1.8)	2.0 (1.4 to 2.7)	4.2 (3.5 to 5.4)
Max	0.9 (0.4 to 1.4)	1.0 (0.6 to 1.3)	1.1 (0.7 to 1.4)	1.1 (0.6 to 1.6)	1.4 (0.6 to 2.2)	1.8 (0.9 to 2.9)	1.0 (0.5 to 1.9)	1.9 (1.3 to 2.9)	3.8 (3.0 to 5.1)

	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
RANGELANDS (WEST)									
Annual									
Mean	1.0 (0.6 to 1.4)	1.0 (0.6 to 1.5)	1.1 (0.8 to 1.5)	1.2 (0.8 to 1.7)	1.5 (1.0 to 2.1)	2.1 (1.5 to 2.6)	1.1 (0.6 to 1.9)	2.1 (1.5 to 3.1)	4.4 (3.1 to 5.6)
Min	0.8 (0.6 to 1.2)	1.0 (0.6 to 1.4)	1.1 (0.8 to 1.5)	1.0 0.7 to 1.7)	1.4 (1.0 to 2.0)	2.0 (1.6 to 2.6)	1.0 (0.4 to 1.7)	2.0 (1.4 to 2.9)	4.3 (3.3 to 5.6)
Max	1.0 (0.6 to 1.5)	1.1 (0.7 to 1.6)	2.1 (1.6 to 2.8)	1.4 (0.8 to 2.0)	1.6 (1.0 to 2.3)	2.1 (1.6 to 2.8)	1.3 (0.7 to 2.1)	2.3 (1.4 to 3.3)	4.5 (3.1 to 5.8)
Summer									
Mean	0.9 (0.6 to 1.4)	1.0 (0.5 to 1.7)	1.0 (0.7 to 1.6)	1.3 (0.7 to 2.0)	1.5 (0.9 to 2.3)	1.9 (1.2 to 2.8)	1.1 (0.5 to 2.1)	2.2 (1.2 to 3.3)	4.1 (2.6 to 5.9)
Min	0.9 (0.6 to 1.2)	1.0 (0.6 to 1.5)	1.1 (0.8 to 1.7)	1.1 (0.7 to 1.8)	1.4 (1.1 to 2.3)	2.0 (1.4 to 2.8)	1.0 (0.6 to 1.8)	2.0 (1.3 to 3.1)	4.1 (2.7 to 5.5)
Max	1.0 (0.6 to 1.6)	1.1 (0.5 to 1.7)	1.1 (0.7 to 1.7)	1.3 (0.8 to 2.1)	1.5 (0.8 to 2.3)	2.1 (1.3 to 2.9)	1.6 (0.5 to 2.6)	2.3 (1.2 to 3.7)	4.1 (2.6 to 6.1)
Autumn									
Mean	1.0 (0.5 to 1.3)	1.1 (0.5 to 1.5)	1.1 (0.6 to 1.6)	1.1 (0.7 to 1.8)	1.4 (0.9 to 2.2)	2.0 (1.3 to 2.7)	1.2 (0.7 to 2.0)	2.1 (1.4 to 3.0)	4.3 (2.5 to 5.8)
Min	0.9 (0.5 to 1.1)	1.0 (0.6 to 1.3)	1.1 (0.7 to 1.6)	1.1 (0.6 to 1.6)	1.5 (0.9 to 2.0)	2.1 (1.5 to 2.7)	1.1 (0.4 to 1.7)	2.1 (1.5 to 2.9)	4.5 (3.0 to 5.8)
Max	1.0 (0.4 to 1.4)	1.1 (0.5 to 1.5)	1.2 (0.5 to 1.7)	1.1 (0.6 to 2.0)	1.5 (0.8 to 2.3)	2.0 (1.2 to 2.9)	1.3 (0.8 to 1.8)	2.2 (1.1 to 3.3)	4.2 (2.8 to 6.0)
Winter									
Mean	0.9 (0.5 to 1.4)	1.0 (0.7 to 1.5)	1.1 (0.8 to 1.6)	1.1 (0.7 to 1.8)	1.5 (0.9 to 2.1)	1.9 (1.5 to 2.5)	1.0 (0.6 to 1.8)	2.1 (1.5 to 2.9)	4.4 (3.3 to 5.4)
Min	0.7 (0.4 to 1.3)	1.0 (0.6 to 1.4)	0.9 (0.3 to 1.2)	1.0 (0.6 to 1.6)	1.3 (0.8 to 2.0)	1.9 (1.5 to 2.5)	0.9 (0.3 to 1.7)	2.0 (1.3 to 2.9)	4.2 (3.3 to 5.3)
Max	1.0 (0.5 to 1.4)	1.1 (0.7 to 1.5)	1.3 (0.8 to 1.7)	1.2 (0.7 to 1.8)	1.7 (1.0 to 2.3)	2.0 (1.6 to 2.6)	1.2 (0.7 to 1.9)	2.2 (1.3 to 3.0)	4.8 (3.3 to 5.6)
Spring									
Mean	0.9 (0.5 to 1.5)	1.1 (0.6 to 1.6)	1.2 (0.7 to 1.6)	1.2 (0.4 to 1.9)	1.6 (1.0 to 2.4)	2.2 (1.5 to 2.9)	1.2 (0.5 to 1.9)	2.2 (1.5 to 3.2)	4.7 (3.3 to 6.2)
Min	0.9 (0.3 to 1.5)	1.1 (0.4 to 1.6)	1.2 (0.6 to 1.7)	1.1 (0.5 to 1.8)	1.5 (0.9 to 2.3)	2.1 (1.5 to 3.0)	1.2 (0.3 to 1.9)	2.2 (1.3 to 3.3)	4.5 (3.4 to 6.0)
Max	1.1 (0.4 to 1.7)	1.1 (0.6 to 1.7)	1.3 (0.7 to 1.8)	1.4 (0.3 to 2.1)	1.7 (0.9 to 2.6)	2.2 (1.6 to 2.9)	1.3 (0.5 to 2.1)	2.4 (1.3 to 3.4)	4.7 (3.3 to 6.2)

Table A2. Annual number of days over 35°C and 40°C. Towns shaded green are in the Monsoonal North cluster and towns shaded orange are in the Rangelands cluster. Value is average of eight models and range is lowest and highest model value.
(Source: www.climatechangeinaustralia.gov.au)

Threshold	Historical (1981–2010)	2030 (2016–2045)		2050 (2036–2065)		2090 (2075–2104)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
MILIKAPITI							
35°C or above	6	23 (13 to 39)	28 (14 to 50)	41 (24 to 67)	65 (34 to 102)	70 (42 to 102)	205 (155 to 250)
40°C or above	0	0	0	0	0	0	0
DARWIN							
35°C or above	47	107 (80 to 133)	118 (82 to 156)	139 (108 to 172)	176 (136 to 209)	184 (152 to 214)	288 (256 to 317)
40°C or above	0	0	0	0	0	0	5 (1 to 11)
JABIRU							
35°C or above	135	191 (169 to 214)	198 (172 to 224)	212 (187 to 233)	238 (203 to 267)	243 (219 to 266)	310 (284 to 332)
40°C or above	2	7 (3 to 11)	8 (3 to 13)	12 (5 to 21)	21 (8 to 31)	19 (9 to 28)	70 (29 to 111)
NHULUNBUY							
35°C or above	7	17 (12 to 22)	19 (14 to 27)	26 (18 to 35)	38 (23 to 53)	38 (26 to 51)	121 (80 to 173)
40°C or above	0	0	0	0	0	0	0
BATCHELOR							
35°C or above	86	142 (119 to 160)	153 (124 to 180)	168 (144 to 193)	199 (168 to 226)	205 (177 to 229)	291 (261 to 318)
40°C or above	0	1 (1 to 2)	2 (1 to 3)	2 (1 to 4)	5 (2 to 8)	5 (2 to 7)	32 (10 to 53)
PINE CREEK							
35°C or above	110	159 (137 to 176)	169 (146 to 188)	179 (160 to 197)	208 (181 to 231)	211 (187 to 230)	282 (253 to 309)
40°C or above	1	4 (1 to 6)	4 (2 to 9)	7 (3 to 12)	14 (5 to 22)	12 (5 to 20)	57 (17 to 90)
KATHERINE							
35°C or above	157	200 (178 to 214)	208 (189 to 220)	216 (198 to 231)	240 (218 to 255)	242 (225 to 255)	298 (274 to 320)
40°C or above	7	19 (11 to 27)	22 (14 to 35)	28 (18 to 39)	43 (24 to 57)	38 (21 to 51)	101 (54 to 138)
BORROLOOLA							
35°C or above	125	154 (134 to 167)	164 (144 to 179)	171 (149 to 189)	194 (170 to 213)	196 (178 to 213)	255 (221 to 286)
40°C or above	5	11 (7 to 14)	12 (8 to 18)	15 (9 to 23)	24 (13 to 37)	21 (12 to 35)	69 (29 to 98)
ELLIOTT							
35°C or above	182	211 (198 to 224)	216 (198 to 226)	222 (203 to 237)	239 (222 to 253)	241 (226 to 250)	280 (248 to 300)
40°C or above	46	67 (54 to 78)	73 (55 to 91)	80 (66 to 96)	101 (76 to 125)	96 (78 to 114)	153 (99 to 185)
TENNANT CREEK							
35°C or above	136	160 (147 to 175)	166 (149 to 180)	169 (150 to 188)	188 (168 to 205)	187 (167 to 205)	228 (178 to 252)
40°C or above	22	40 (27 to 57)	45 (26 to 69)	50 (35 to 75)	68 (43 to 99)	61 (39 to 89)	115 (60 to 150)
ALICE SPRINGS							
35°C or above	90	110 (100 to 124)	113 (100 to 130)	118 (103 to 144)	135 (112 to 160)	132 (113 to 158)	172 (121 to 205)
40°C or above	14	27 (17 to 44)	29 (18 to 50)	35 (21 to 61)	48 (30 to 76)	43 (28 to 69)	86 (40 to 128)
YULARA							
35°C or above	104	122 (111 to 133)	124.68 (116 to 140)	130 (117 to 151)	145 (127 to 169)	143 (126 to 161)	178 (134 to 207)
40°C or above	26	42 (32 to 61)	44 (34 to 63)	50 (39 to 74)	63 (46 to 93)	59 (46 to 80)	99 (57 to 140)

Table A3. Change in average rainfall (%) relative to 1995 (1986–2005). Note that changes in the dry season can appear large because they are changes on a small amount.

MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-2 (-10 to +5)	0 (-11 to +6)	0 (-6 to +6)	-3 (-10 to +5)	0 (-10 to +7)	-1 (-14 to +9)	-5 (-11 to +4)	-1 (-13 to +8)	+4 (-24 to +19)
Wet	0 (-8 to +6)	0 (-8 to +6)	-1 (-5 to +7)	-3 (-10 to +6)	+1 (-7 to +7)	0 (-7 to +8)	-3 (-11 to +5)	0 (-11 to +8)	+4 (-23 to +19)
Dry	-7 (-32 to +17)	-5 (-35 to +19)	-5 (-22 to +29)	-11 (-27 to +12)	-11 (-35 to 5)	-6 (-40 to +26)	-7 (-29 to +7)	-6 (-30 to +22)	-4 (-45 to +44)
RANGELANDS (NORTH)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-2 (-12 to +7)	-2 (-11 to +7)	-1 (-11 to +8)	-4 (-18 to +4)	-1 (-12 to +8)	-2 (-17 to +9)	-7 (-19 to +3)	-5 (-16 to +9)	-4 (-31 to +19)
Summer	-4 (-13 to +8)	0 (-12 to +8)	0 (-11 to +17)	-5 (-17 to +7)	+1 (-12 to +13)	-1 (-16 to +13)	-7 (-22 to +8)	-3 (-17 to +10)	+4 (-21 to +26)
Autumn	-2 (-18 to +25)	-1 (-24 to +22)	0 (-24 to +20)	-1 (-26 to +21)	-1 (-17 to +21)	+1 (-20 to +22)	-7 (-24 to +20)	-2 (-22 to +33)	6 (-40 to +39)
Winter	-3 (-22 to +11)	-7 (-27 to +19)	-10 (-31 to +18)	-8 (-37 to +13)	-9 (-30 to +9)	-10 (-32 to +23)	-6 (-35 to +15)	-11 (-32 to +7)	-22 (-58 to 35)
Spring	-3 (-22 to +21)	-1 (-25 to +22)	-3 (-20 to +13)	-6 (-39 to +14)	-4 (-29 to +12)	-4 (-39 to +18)	-5 (-31 to +17)	-9 (-32 to +12)	-14 (-53 to +26)

Table A4. Change in relative humidity (%) relative to 1995 (1986–2005).

MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-0.5 (-2.2 to 0.5)	0.1 (-1.6 to 0.7)	-0.3 (-1.3 to 0.4)	-0.9 (-2.2 to 0.9)	-0.4 (-2.2 to 0.8)	-0.5 (-2.3 to 0.9)	-1.0 (-3.1 to 0.4)	-0.7 (-3.5 to 0.6)	-0.9 (-6.3 to 1.4)
Wet	-1.0 (-2.7 to 1.1)	-0.5 (-2.3 to 1.5)	-0.9 (-2.8 to 0.8)	-1.0 (-4.8 to 0.5)	-0.8 (-4.6 to 3.4)	-0.9 (-5.6 to 3.2)	-2.1 (-4.7 to 0.1)	-1.3 (-5.0 to 1.0)	-1.7 (-7.2 to 3.0)
Dry	-0.9 (-3.3 to 0.8)	-0.5 (-3.4 to 1.8)	-0.7 (-2.7 to 1.3)	-1.7 (-3.6 to 1.8)	-1.0 (-6.7 to 3.7)	-1.3 (-6.1 to 3.5)	-1.0 (-5.2 to 0.6)	-1.0 (-6.6 to 1.3)	-2.0 (-12.5 to 3.2)
RANGELANDS (NORTH)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	-0.6 (-3.1 to 0.7)	-0.3 (-2.1 to 0.8)	-0.7 (-1.9 to 0.9)	-0.6 (-2.9 to 0.3)	-0.5 (-4.0 to 1.1)	-1.0 (-3.3 to 0.9)	-1.5 (-3.5 to 0.1)	-1.1 (-4.8 to 0.1)	-1.9 (-7.3 to 1.1)
Summer	-1.2 (-3.6 to 1.3)	-0.4 (-2.7 to 1.6)	-0.4 (-2.4 to 1.4)	-1.0 (-3.4 to 0.4)	-0.3 (-3.2 to 1.8)	-0.9 (-4.7 to 1.3)	-2.8 (-4.6 to 1.0)	-0.6 (-5.2 to 1.1)	-1.2 (-6.3 to 2.4)
Autumn	-0.7 (-5.6 to 3.2)	-0.3 (-4.2 to 2.4)	-0.5 (-2.9 to 2.0)	-0.1 (-6.3 to 2.5)	-0.7 (-4.5 to 2.6)	-1.0 (-5.8 to 3.2)	-2.0 (-4.7 to 1.2)	-0.9 (-7.7 to 3.0)	-1.4 (-10.6 to 4.3)
Winter	-0.7 (-3.3 to 1.0)	-0.7 (-3.1 to 0.9)	-1.1 (-3.3 to 0.5)	-1.3 -3.9 to 0.3)	-1.4 (-4.5 to 0.4)	-1.2 (-5.2 to 2.1)	-1.1 (-4.3 to 1.0)	-1.8 (-5.1 to -0.1)	-3.7 (-10.9 to 0.3)
Spring	-0.6 (-4.5 to 1.4)	-0.5 (-3.4 to 1.3)	-0.5 (-3.0 to 1.1)	-0.9 (-3.5 to 1.8)	-0.8 (-2.9 to 1.5)	-0.6 (-3.8 to 1.5)	-0.8 (-4.0 to 0.9)	-1.5 (-4.1 to 1.1)	-2.7 (-7.3 to 1.5)

Table A5. Change in potential evapotranspiration (%) relative to 1995 (1986–2005).

MONSOONAL NORTH (WEST)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	2.8 (1.4 to 3.6)	3.2 (1.4 to 4.0)	3.2 (2.1 to 4.8)	3.4 (1.5 to 5.1)	4.3 (1.9 to 6.8)	6.2 (4.1 to 8.3)	3.6 (2.2 to 5.8)	6.8 (4.0 to 8.5)	12.2 (7.8 to 16.7)
Wet	Not available	2.8 (1.0 to 4.1)	3.1 (1.5 to 4.2)	Not available	3.8 (0.4 to 7.6)	5.1 (1.5 to 9.5)	Not available	5.9 (2.9 to 8.2)	9.9 (4.9 to 14.9)
Dry	Not available	3.4 (1.4 to 5.3)	3.8 (2.5 to 5.0)	Not available	4.8 (1.8 to 7.8)	7.2 (3.2 to 10.4)	Not available	6.7 (4.8 to 8.9)	14.4 (10.6 to 18.2)
RANGELANDS (NORTH)									
	2030 (2020–2039)			2050 (2040–2059)			2090 (2080–2099)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Annual	2.8 (1.0 to 4.5)	2.4 (1.1 to 4.5)	3.1 (1.4 to 4.2)	3.4 (-0.6 to 5.2)	4.5 (1.6 to 6.6)	5.5 (3.1 to 7.9)	2.5 (-0.4 to 4.5)	5.1 (3.3 to 8.4)	11.7 (6.7 to 17.7)
Summer	2.6 (1.5 to 4.0)	2.6 (0.8 to 4.5)	2.8 (1.2 to 5.1)	3.3 (0.7 to 4.7)	4.8 (1.0 to 7.7)	5.3 (3.1 to 7.9)	2.3 (0.1 to 6.4)	5.2 (3.0 to 9.5)	12.2 (7.8 to 17.3)
Autumn	2.4 (0.4 to 6.1)	3.1 (-0.9 to 4.9)	2.6 (0.1 to 6.0)	3.2 (-0.7 to 8.6)	4.4 (0.6 to 8.3)	6.0 (3.9 to 12.2)	2.0 (-1.1 to 6.1)	5.7 (2.3 to 10.2)	13.8 (6.1 to 20.4)
Winter	2.4 (-0.2 to 4.4)	2.4 (-0.2 to 5.5)	2.3 (-0.5 to 5.3)	2.8 (0.2 to 6.7)	3.6 (0.4 to 6.6)	4.5 (0.8 to 10.0)	2.3 (-1.8 to 6.7)	5.1 (1.7 to 8.8)	11.8 (3.8 to 18.2)
Spring	2.6 (-0.7 to 6.6)	2.8 (-0.1 to 5.4)	2.7 (0.7 to 5.7)	2.9 (-1.3 to 5.5)	3.6 (1.0 to 6.8)	5.1 (1.1 to 8.7)	1.8 (-0.9 to 4.8)	5.0 (1.6 to 7.8)	10.7 (4.2 to 16.1)

Table A6. Projected sea-level rise and allowances (m) relative to 1986–2005 for coastal local government areas in the Northern Territory. (Source: CoastAdapt at www.coastadapt.com.au)

LGA	2030 (2020–2040)			2050 (2040–2050)			2090 (2080–2100)		
	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Belyuen									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.44	0.52	0.72
Darwin									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.44	0.52	0.72
East Arnhem									
SLR	0.11 (0.07 to 0.16)	0.11 (0.07 to 0.16)	0.12 (0.07 to 0.16)	0.20 (0.12 to 0.27)	0.21 (0.14 to 0.29)	0.24 (0.16 to 0.32)	0.37 (0.21 to 0.54)	0.45 (0.27 to 0.63)	0.60 (0.40 to 0.83)
Allowance	0.11	0.12	0.12	0.21	0.22	0.25	0.43	0.51	0.70
Litchfield									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.44	0.53	0.73
Roper Gulf									
SLR	0.11 (0.06 to 0.15)	0.11 (0.07 to 0.15)	0.11 (0.07 to 0.16)	0.19 (0.11 to 0.27)	0.20 (0.13 to 0.28)	0.23 (0.15 to 0.31)	0.35 (0.19 to 0.51)	0.43 (0.26 to 0.61)	0.59 (0.38 to 0.81)
Allowance	0.11	0.11	0.11	0.20	0.21	0.24	0.39	0.47	0.65
Tiwi Islands									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.45	0.53	0.73
Victoria Daly									
SLR	0.11 (0.07 to 0.15)	0.12 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.20 (0.12 to 0.27)	0.21 (0.14 to 0.29)	0.24 (0.16 to 0.32)	0.37 (0.21 to 0.53)	0.45 (0.27 to 0.63)	0.60 (0.40 to 0.83)
Allowance	0.12	0.12	0.12	0.21	0.23	0.26	0.43	0.51	0.71
Wagait									
SLR	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.20 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.38 (0.22 to 0.55)	0.46 (0.28 to 0.64)	0.62 (0.41 to 0.85)
Allowance	0.12	0.12	0.13	0.22	0.23	0.26	0.44	0.52	0.72
West Arnhem									
SLR	0.12 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.12 (0.08 to 0.17)	0.21 (0.13 to 0.28)	0.22 (0.14 to 0.30)	0.25 (0.17 to 0.33)	0.39 (0.22 to 0.56)	0.46 (0.29 to 0.65)	0.62 (0.41 to 0.85)
Allowance	0.12	0.13	0.13	0.23	0.25	0.28	0.52	0.61	0.85
West Daly									
SLR	0.11 (0.07 to 0.15)	0.12 (0.07 to 0.16)	0.12 (0.08 to 0.16)	0.20 (0.12 to 0.27)	0.21 (0.14 to 0.29)	0.24 (0.16 to 0.32)	0.37 (0.21 to 0.53)	0.45 (0.27 to 0.63)	0.60 (0.40 to 0.83)
Allowance	0.12	0.12	0.12	0.21	0.23	0.26	0.43	0.51	0.71

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