

# climatechange in Australia



Projections developed by CSIRO and the  
Australian Bureau of Meteorology for the  
Australian Climate Change Science Programme

observed changes and projections





Warming of the global climate system over the past century is beyond doubt, as seen in atmospheric and oceanic temperatures, sea level rise and melting of snow and ice. It is very likely that most of the global warming since the mid-20th century is due to human activities that have increased greenhouse gas levels.

Further global warming and regional climate change is expected due to projected increases in greenhouse gases. Impacts will vary across regions and sectors<sup>1</sup>. While global warming can be slowed through large reductions in greenhouse gas emissions, some warming is unavoidable and adaptation will be needed<sup>1</sup>. A key part of planning for climate change is having access to detailed and reliable regional projections of climate change.

This brochure summarises the latest information about observed climate change over Australia, the likely causes, future global climate change and regional projections for Australia. It is based on international climate change research, including conclusions from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)<sup>2</sup>, and builds on a large body of climate research that has been undertaken for the Australian region in recent years. This includes research completed within the Australian Climate Change Science Programme by CSIRO and the Australian Bureau of Meteorology in partnership with the Australian Greenhouse Office. The brochure summarises a more detailed assessment available in an accompanying technical report<sup>3</sup>.

## Observed changes

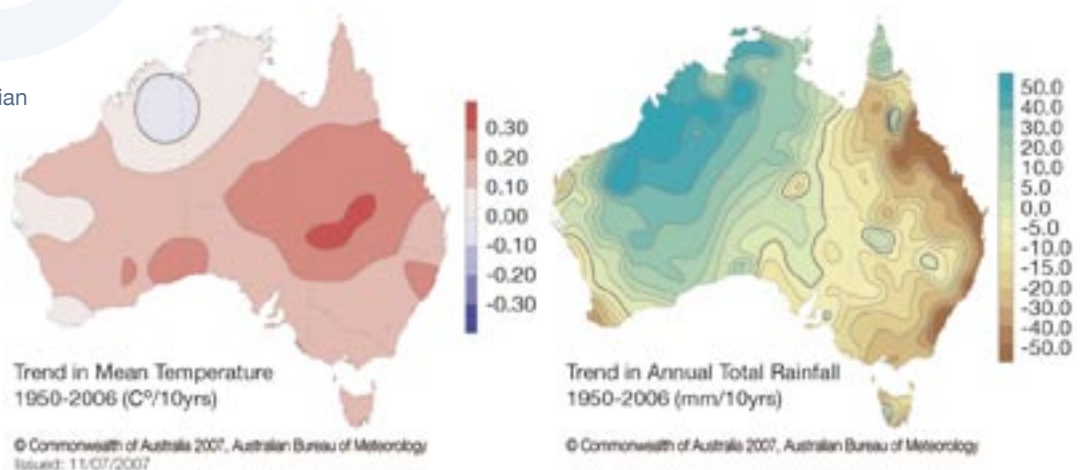
### Temperature and rainfall

Australian average temperatures have increased 0.9°C since 1950, with significant regional variations (Figure 1). The frequency of hot days and nights has increased and the frequency of cold days and nights has declined.

Since 1950, most of eastern and south-western Australia has experienced substantial rainfall declines (Figure 1). Across New South Wales and Queensland these rainfall trends partly reflect a very wet period around the 1950s, though recent years have been unusually dry. In contrast, north-west Australia has become wetter over this period, mostly during summer.

From 1950 to 2005, extreme daily rainfall intensity and frequency has increased in north-western and central Australia and over the western tablelands of New South Wales, but decreased in the south-east and south-west and along the central east coast.

**Figure 1:** Trends in annual mean Australian temperature and rainfall since 1950.





## Oceans

Global sea levels rose by about 17 cm during the 20th century, and by around 10 cm from 1920-2000 at the Australian coastal sites monitored. Substantial warming has also occurred in the three oceans surrounding Australia, particularly off the south-east coast and in the Indian Ocean.

## Causes of past climate change

Increased Australian land temperatures since the middle of the 20th century are likely to be mostly due to increases in greenhouse gases from human activities. So is the rise in the number of warm days and warm nights and fall in cool days and cool nights.

The rainfall decrease in south-western Australia since the mid-1970s is likely to be at least partly due to human-induced increases in greenhouse gases.



## Climate change projections

The IPCC developed a range of greenhouse gas and sulphate aerosol emissions scenarios for the 21st century based on various assumptions about demographic, economic and technological factors likely to influence future emissions<sup>4</sup>. Corresponding scenarios for future atmospheric concentrations of greenhouse gases and sulphate aerosols can be converted to a radiative forcing of the climate system. Positive forcing leads to warming while negative forcing leads to cooling. Changes in radiative forcing are used as input to climate models.

Climate models are the best tools we have for projecting the future climate. A climate model is a mathematical representation of the Earth's climate system based on well-established laws of physics, but involving simplifications of biophysical processes. Projections are not predictions because they are conditional on the emission scenarios and on the reliability of climate models.

Climate change simulations for the 20th and 21st centuries are available from 23 global climate models. Each model is given a score based on its ability to simulate average (1961-1990) patterns of temperature, rainfall and mean sea level pressure in the Australian region. Models with higher scores are given greater emphasis in developing regional projections.

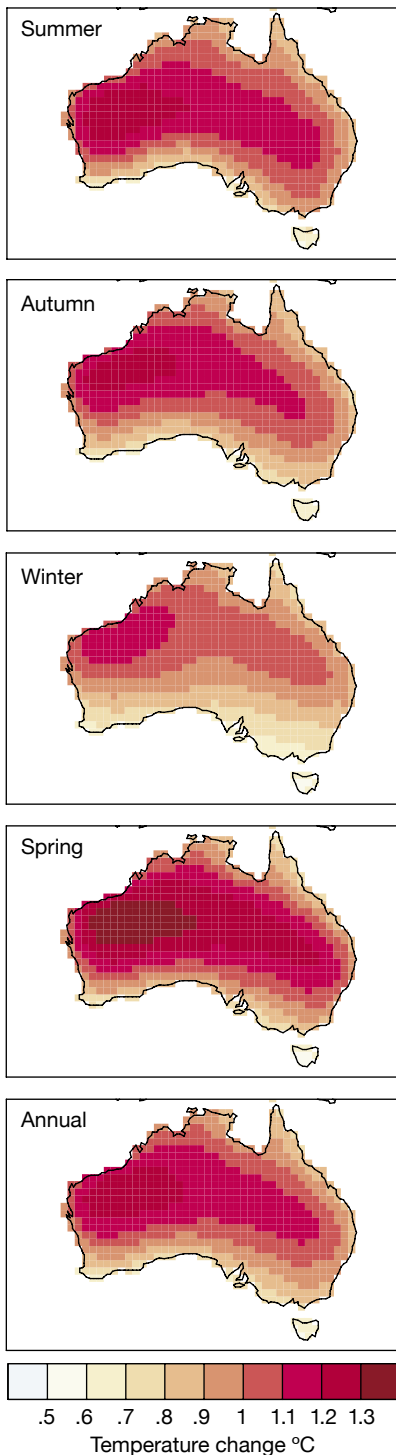
The regional projections presented here are relative to the period 1980-1999. For convenience, the baseline is called 1990. Projections are given here for 2030 and 2070. The projections give an estimate of the

average climate around these years under future greenhouse gas emission scenarios, taking into account the consistency among models. Individual years will, of course, show some variation from this average.

Uncertainties in projected regional climate change in 2030 are mostly due to differences between the results of the climate models rather than the different emission scenarios. So projections for 2030 are given for a mid-range emission scenario (the IPCC's A1B scenario<sup>4</sup>). Beyond 2030, the magnitude of projected climate changes is much more strongly affected by emissions, so results for 2070 are given for a low emissions case (the B1 scenario<sup>4</sup>) and for a high emissions case (the A1FI scenario<sup>4</sup>).

To represent the uncertainty due to differences between climate model results, probability distributions have been fitted to the range of results for temperature, rainfall and some other climate variables. This allowed us to give a best estimate based on the 50th percentile (the mid-point of spread of model results), and a range of uncertainty based on 10th and 90th percentiles (lowest 10% and highest 10% of the spread of model results). It also allowed us to calculate the probability of a change in climate greater than a given threshold, based on the spread of model results.

Note that not all of the uncertainty associated with projecting future global and regional climate change can be easily quantified. Changes outside the ranges given here, and particularly those beyond the upper limit of the ranges given for 2070, cannot be excluded, although the likelihood of this occurrence cannot be estimated at this stage.



**Figure 2:** Best estimate (50th percentiles) of projected mean warming (°C) by 2030 relative to 1990 for mid-range emissions (A1B scenario<sup>4</sup>).

## Australia's future climate

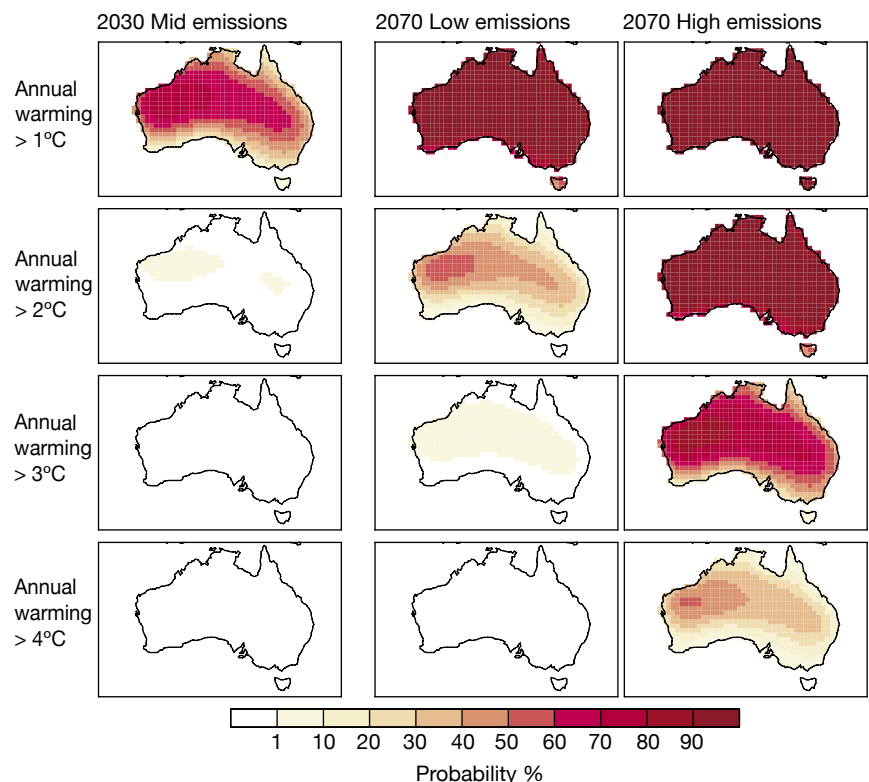
### Temperature

The best estimate of annual warming over Australia by 2030 relative to 1990 is about 1.0°C for the mid-range emissions. Warming will be a little less in coastal areas and a little more inland. The pattern varies little seasonally (Figure 2), although warming is less in winter in the south. The range of uncertainty due to differences between models is about 0.6°C to 1.5°C for most of Australia, with the probability of the warming exceeding 1°C by 2030 being 10–20% for coastal areas, and more than 50% for inland regions (Figure 3).

Later in the century, the warming is more dependent upon the assumed emission scenario. By 2070, the

annual warming is around 1.8°C (range of 1.0°C to 2.5°C) for the low emissions case and around 3.4°C (range of 2.2°C to 5.0°C) for the high emissions case. By 2070 for the low emissions case, there is a greater than 90% likelihood of warming exceeding 1°C throughout Australia, a 20–60% chance of exceeding 2°C over most inland areas, and about a 10% chance of exceeding 2°C in most coastal areas (Figure 3). For the high emissions case there is around a 30% chance of exceeding 3°C in southern and eastern coastal areas and a much greater chance inland, while the chance of exceeding 4°C is around 10% in most coastal areas and 20–50% inland.

Substantial increases in the frequency of days over 35°C are likely (Table 1). Fewer frosts are also likely.



**Figure 3:** Probability of exceeding various annual warming thresholds, relative to 1990, based on the spread of climate model results. The mid, low and high emissions are A1B, B1 and A1FI<sup>4</sup>.



**Table 1:** Average number of days per year above 35°C at selected sites for present (1971-2000) climate and best estimate values for 2030 and 2070, with ranges of uncertainty in brackets. The mid, low and high emissions are A1B, B1 and A1FI<sup>4</sup>.

	Present average (1971-2000)	2030 average (mid emissions)	2070 average (low emissions)	2070 average (high emissions)
Sydney	3.5	4.4 (4.1-5.1)	5.3 (4.5-6.6)	8.2 (6-12)
Melbourne	9.1	11.4 (11-13)	14 (12-17)	20 (15-26)
Adelaide	17	23 (21-26)	26 (24-31)	36 (29-47)
Brisbane	1.0	2.0 (1.5-2.5)	3.0 (2.1-4.6)	7.6 (4-21)
Hobart	1.4	1.7 (1.6-1.8)	1.8 (1.7-2.0)	2.4 (2.0-3.4)
Perth	28	35 (33-39)	41 (36-46)	54 (44-67)
Darwin	11	44 (28-69)	89 (49-153)	230 (140-308)

## Rainfall

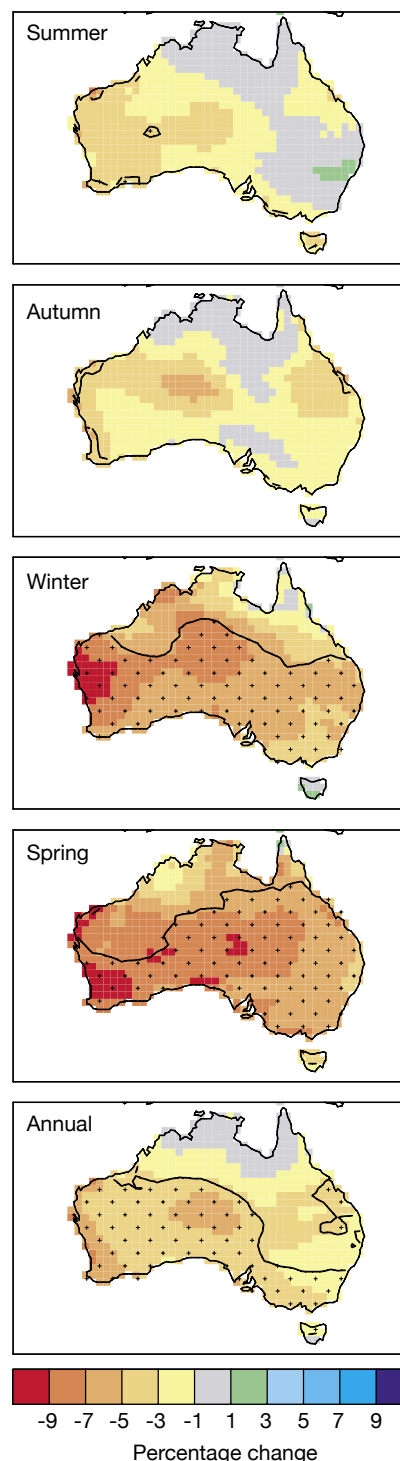
Unlike temperature which is always simulated to increase, climate model results for rainfall change show decreases and increases for many locations. Where at least two-thirds of the spread of model results are less than zero, decreasing rainfall is considered 'likely'. Decreases in rainfall are likely in southern areas in the annual average and in winter, in southern and eastern areas in spring, and along the west coast in autumn (Figure 4). Otherwise the models do not give a likely direction of rainfall change, although model ranges show a tendency to decrease in most cases. In no region or season do models suggest a 'likely' increase in rainfall.

For 2030, best estimates of annual rainfall change indicate little change in the far north and decreases of 2% to 5% elsewhere (Figure 4). Decreases of around 5% prevail in winter and spring, particularly in the south-west where they reach 10%. In summer and autumn, decreases are smaller and there are slight increases in New South Wales in summer.

The range of rainfall change in 2030, allowing for differences between models, is large. Annually averaged, it is

around -10% to +5% in northern areas and -10% to little change in southern areas. Winter and spring changes range from -10% to little change in southern areas of the south-east of the continent, -15% to little change in the south-west, and -15% to +5% in eastern areas. In summer and autumn, the range is typically -15% to +10%. There is a 20% to 30% chance of a simulated annual rainfall decrease of at least 10% in western and central areas, whereas the probability of a simulated increase of at least 10% is very low (Figure 5). Decadal-scale natural variability in rainfall is comparable in magnitude to these projected changes and may therefore mask, or significantly enhance, the greenhouse-induced changes.

In 2070 for the low emissions case, the range of annual rainfall change is -20% to +10% in central, eastern and northern areas, with a best estimate of little change in the far north grading to around -7.5% elsewhere. The range of change in southern areas is from -20% to little change, with a best estimate of around -7.5%. Seasonal changes follow the pattern seen for 2030, but are correspondingly larger. There is a 40% to 50% chance of a simulated annual rainfall decrease of at least



**Figure 4:** Best estimate (50th percentile) of projected rainfall change (%) for 2030 relative to 1990 under a mid-range emissions (A1B) scenario<sup>4</sup>. Stippling indicates where a decrease is 'likely' (more than two thirds of the model range less than zero). No areas show a 'likely' increase.

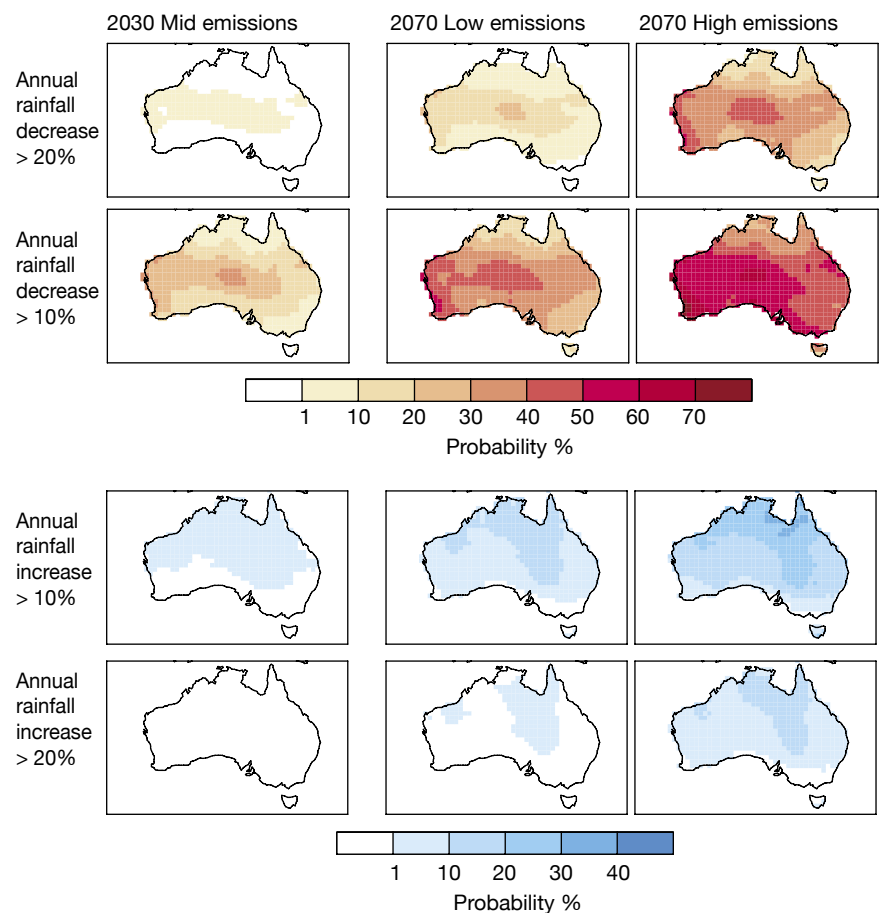




10% in western and central areas, and there is a 10% to 20% chance of rainfall decreases of at least 20% in these areas (Figure 5). There is a 10% to 20% chance of rainfall increases of at least 10% in parts of the north.

In 2070 for the high emissions case, the range of annual rainfall change in central, eastern and northern areas grows to -30% to +20%, with a best estimate of little change in the far north grading to around -10% in the south-west. The range of change in southern areas is from -30% to +5%, with a best estimate of around -10%. Seasonal changes may be larger, with projected winter and spring decreases in the south-west of up to 40%. There is a 40% to 50% chance of rainfall decreases of at least 20% in the south-west (Figure 5). There is a 10% to 20% chance of rainfall increases of at least 20% in the north.

Models also show an increase in daily rainfall intensity (rain per rainy day) and in the number of dry days. Extreme daily rainfall tends to increase in many areas but not in the south in winter and spring when there is a strong decrease in mean rainfall.



**Figure 5:** Probability (%) of annual rainfall change, relative to 1990, exceeding various thresholds based on the spread of climate model results. The mid, low and high emissions are A1B, B1 and A1FI<sup>4</sup>.

## Applications of projections to risk management and impact assessment

General purpose climate change projections can assist in identifying risks posed by climate change for human and natural systems. See *Climate Change Impacts and Risk Management: a Guide for Business and Government*<sup>6</sup> for some thoughts on how to apply a risk management approach to climate change impacts.

Some applications may require more detailed impact analysis. Care

must be exercised when using the projections for detailed analysis, particularly when selecting climate variables, determining temporal and/or spatial resolution, and dealing with uncertainty. Detailed impacts studies generally require purpose-built climate projections, including time series, which are beyond the scope of the projections presented here.

## Extreme events

### Drought

Due to projected changes in rainfall and increases in evaporation, soil moisture is likely to decline over much of southern Australia. If a drought-month is defined as having very low soil moisture (within the driest 10% for the period 1974-2003), simulations from two models show up to 20% more drought-months over most of Australia by 2030, with up to 40% more drought-months by 2070 in eastern Australia, and up to 80% more in south-western Australia by 2070.



## Fire weather

An increase in fire-weather risk is likely with warmer and drier conditions. Simulations from two models show the number of days with very high and extreme fire danger ratings increases 4-25% by 2020 and 15-70% by 2050. For example, Canberra has an annual average of 26-29 very high or extreme fire danger days by 2020 and 28-38 days by 2050, compared

with a present average of 23 days. It is likely that the fire season will lengthen, shifting periods suitable for prescribed burning toward winter.

## Storm surges

There is potential for significant increases in inundation due to higher mean sea level and more intense weather systems.

## Severe weather

Regional studies indicate a likely increase in the proportion of tropical cyclones in the more intense categories, but a possible decrease in the total number of cyclones. There is a possible reduction in cool season tornadoes in southern Australia, and hail risk may increase over the south-east coast.

## Uncertainties

Although our understanding of climate change has improved markedly over the past several decades, climate change projections are still subject to the following uncertainties:

- Socio-economic uncertainties associated with the current and future activities of humans, which affect the development of greenhouse gas and aerosol emission scenarios.
- Uncertainties associated with our understanding of how the Earth's major biophysical systems behave and how they are represented in climate models.
- Uncertainties regarding the assignment of probability distributions to regional climate change projections.
- Uncertainties associated with projecting climate change at small spatial scales, particularly for coastal and mountainous areas.

The preparation of global and regional climate change projections is an active area of research. Methods are evolving and additional model results regularly become available. Future research will address major issues of concern such as changes in Australian summer and autumn rainfall, tropical cyclones and El Niño – Southern Oscillation, and interaction between decadal-scale natural climate variability and climate change.

### Projected changes to other aspects of climate, based primarily on global climate model results

Variable	Projected changes
Solar radiation	Climate models indicate little change, although a tendency for increases in southern areas of Australia is evident, particularly in winter and spring.
Relative humidity	Small decreases simulated over most of Australia.
Potential evapotranspiration	Climate models indicate increases, especially in the north and east.
Wind	Climate models indicate increases in most coastal areas except for band around latitude 30°S in winter and 40°S in summer where there are decreases.
Snow	Decrease in snow cover, average season lengths and peak snow depths, and a tendency for maximum snow depth to occur earlier in the season.
Sea level rise	A global-average rise of 18-59 cm by 2100 is projected, with a possible additional contribution from ice sheets of 10-20 cm. However, further ice sheet contributions may substantially increase the upper limit of sea level rise.
Ocean temperature	Higher sea surface temperatures. The 2030 best estimate is 0.6-0.9°C in the southern Tasman Sea and off the north-west coast and 0.3-0.6°C elsewhere.
Ocean acidity	Increases in ocean acidity due to increased oceanic absorption of carbon dioxide, with the largest increases in the high- to mid-latitudes.
East Australian Current	May increase resulting in warmer waters extending further southward with possible impacts on severe storms and marine ecosystems.
El Niño – Southern Oscillation	In south-eastern Australia, El Niño events may tend to become drier and La Niña events may tend to become wetter.



**Australian Government**  
**Bureau of Meteorology**

Department of the Environment and Water Resources  
Australian Greenhouse Office

[www.climatechangeinaustralia.gov.au](http://www.climatechangeinaustralia.gov.au)

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