



Office of  
Environment  
& Heritage

AdaptNSW

# Murray Murrumbidgee Climate change snapshot





# Overview of Murray Murrumbidgee Region climate change

Based on long-term (1910–2011) observations, temperatures in the Murray Murrumbidgee Region have been increasing since about 1950, with higher temperatures experienced in recent decades.

The region is projected to continue to warm during the near future (2020–2039) and far future (2060–2079), compared to recent years (1990–2009). The warming is projected to be on average about 0.6°C in the near future, increasing to about 1.9°C in the far future. The number of high temperature days is projected to increase, with fewer potential frost risk nights anticipated.

The warming trend projected for the region is large compared to natural variability in temperature and is of a similar order to the rate of warming projected for other regions of NSW.

The region currently experiences considerable rainfall variability across the region and from year-to-year and this variability is also reflected in the projections. However, all of the models agree that spring rainfall will decrease in the future.

Front Cover: River barge crossing the Murray River in South Australia. Copyright: THPStock. Page 2: The walking track to Mount Kosciuszko in the Snowy Mountains, New South Wales, Australia. Kosciuszko National Park. Copyright: Milosz\_M. Page 4: River red gum on the river Murray River. Copyright: clearviewstock. Page 9: Kangaroos at Geehi camping area, Kosciuszko National Park, NSW, Australia. Copyright: Deb Talan.

# Projected changes



## Projected temperature changes



Maximum temperatures are projected to **increase** in the near future by 0.4 – 1.0°C

Maximum temperatures are projected to **increase** in the far future by 1.6 – 2.5°C



Minimum temperatures are projected to **increase** in the near future by 0.4 – 0.8°C

Minimum temperatures are projected to **increase** in the far future by 1.3 – 2.4°C



The number of hot days will **increase**

The number of cold nights will **decrease**

## Projected rainfall changes



Rainfall is projected to **decrease** in spring

Rainfall is projected to **increase** in summer and autumn

## Projected Forest Fire Danger Index (FFDI) changes



Average fire weather is projected to **increase** in summer and spring

Severe fire weather days is projected to **increase** in summer and spring



# Regional snapshots

## NSW and ACT Regional Climate Modelling project (NARClIM)

The climate change projections in this snapshot are from the NSW and ACT Regional Climate Modelling (NARClIM) project. NARClIM is a multi-agency research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW. NSW Government funding comes from the Office of Environment and Heritage (OEH), Sydney Catchment Authority, Sydney Water, Hunter Water, NSW Office of Water, Transport for NSW, and the Department of Primary Industries.

The NARClIM project has produced a suite of twelve regional climate projections for south-east Australia spanning the range of likely future changes in climate. NARClIM is explicitly designed to sample a large range of possible future climates.

Over 100 climate variables, including temperature, rainfall and wind are available at fine resolution (10km and hourly intervals). The data can be used in impacts and adaptation research, and by local decision makers. The data is also available to the public and will help to better understand possible changes in NSW climate.

## Modelling overview

The NARClIM modelling was mainly undertaken and supervised at the Climate Change Research Centre. NARClIM takes global climate model outputs and downscales these to provide finer, higher resolution climate projections for a range of meteorological variables. The NARClIM project design and the process for choosing climate models has been peer-reviewed and published in the international scientific literature (Evans et. al. 2014, Evans et. al. 2013, Evans et. al. 2012).

Go to [climatechange.environment.nsw.gov.au](http://climatechange.environment.nsw.gov.au) for more information on the modelling project and methods.

Interpreting climate projections can be challenging due to the complexities of our climate systems. 'Model agreement', that is the number of models that agree on the direction of change (for example increasing or decreasing rainfall) is used to determine the confidence in the projected changes. The more models that agree, the greater the confidence in the direction of change.

In this report care should be taken when interpreting changes in rainfall that are presented as the average of all of the climate change projections, especially when the model outputs show changes of both wetting and drying. To understand the spread of potential changes in rainfall the bar charts should be considered along with the maps provided in this document. Help on how to interpret the maps and graphs in this report is provided in Appendix 1.

Summary documents for each of the state planning regions of NSW are available and provide climate change information specific to each region.

The snapshots provide descriptions of climate change projections for two future 20-year time periods: 2020–2039 and 2060–2079.

1. The climate projections for 2020–2039 are described in the snapshots as **NEAR FUTURE, or as 2030**, the latter representing the average for the 20-year period.
2. The climate projections for 2060–2079 are described in the snapshots as **FAR FUTURE, or as 2070**, the latter representing the average of the 20-year period.

Further information about the regions will be released in 2015.

# Introduction

This snapshot presents climate change projections for the Murray Murrumbidgee region of NSW. It outlines some key characteristics of the region, including its current climate, before detailing the projected changes to the region's climate in the near and far future.

## Location and topography

Held in esteem for its quality agricultural exports, the Murray Murrumbidgee region includes the NSW side of the Murray River, as well as the Lachlan and Murrumbidgee rivers. Lying west of the Great Dividing Range, the landscape is dominated by large floodplains and unconfined river valleys.

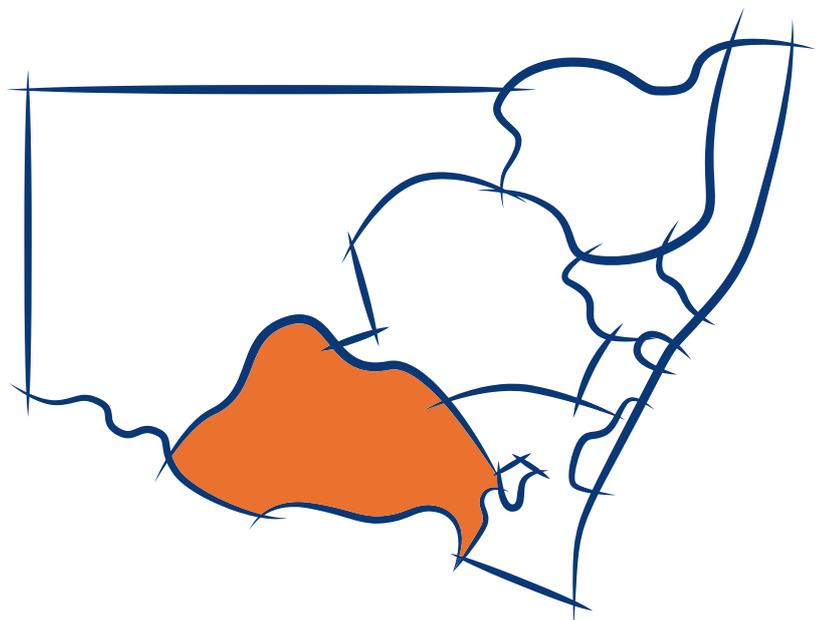
## Population and settlements

The Murray Murrumbidgee Region's major urban centres include Albury–Wodonga, Wagga Wagga and Griffith. The population of approximately 266,350 people is heavily reliant on agriculture, educational services and retail, which are the main employers of the region's approximately 116,900 employees. Areas around the Murray and the Murrumbidgee rivers rely on irrigated water for the production of rice and cotton crops.

## Natural ecosystems

The region includes some of Australia's rarest and most significant natural ecosystems, which range from the highest altitudes of the Australian continent to semi-arid ecosystems in south-west NSW and the Hay Plains. Near Mount Kosciuszko, on the crest of the dividing range feldmark, one of the most restricted alpine vegetation types (28.5 ha) occurs. Further west, relying on the snowmelt and rainfall from the highest peaks are wetland communities associated with the major rivers, including internationally significant Ramsar sites (NSW Central Murray state forests and Fivebough and Tuckerbil swamps).

The range of altitude, rainfall and temperature in the region gives rise to great diversity in flora and fauna. The most widespread species occur on the floodplains of the major rivers that dominate the region. There are a number of species, including threatened species such as feldmark grass and southern corroboree frogs that are confined to habitats of restricted extent.



# Climate of the region

The topography of the Murray Murrumbidgee region results in large spatial variations in climatic conditions. It is relatively wet towards the Snowy Mountains on the eastern boundary of the region, and dry in the west of the region. Summers are warm to hot in the north-west of the region, with cold winters in the Snowy Mountains. Milder conditions are found in the central parts of the region along the South West Slopes with cooler summer temperatures than the plains and warmer winter temperatures than the mountains.

## Temperature

The region experiences a very distinct seasonal variation in temperature. Average maximum temperatures during summer range from 34°C on the plains north of Hay to 14°C in the Snowy Mountains. In winter, the average minimum temperature ranges from -6°C in the Snowy Mountains to 6°C in the west of the region.

Long-term temperature trends indicate that temperatures have been increasing in the since around 1950; however, most of the temperature increase has occurred in the last two decades.

## Temperature extremes

Temperature extremes, both hot and cold, occur infrequently but can have considerable impacts on health, infrastructure and our environment. Changes to temperature extremes often result in greater impacts than changes to average temperatures.

## Hot days

There is a large variation in the number of hot days each year (maximum temperatures above 35°C), ranging from none in the Snowy Mountains to more than 40 hot days in the north-western parts region north of Hay.

## Cold nights

The number of cold nights per year (minimum temperatures below 2°C) varies considerably across the region. Western parts of the region experience the least number of cold nights (fewer than 30 per year). The number of cold nights increases moving to the east and into the mountains. Wagga Wagga sees around 50 cold nights per year and there are over 200 cold nights per year in the peaks of the Snowy Mountains.

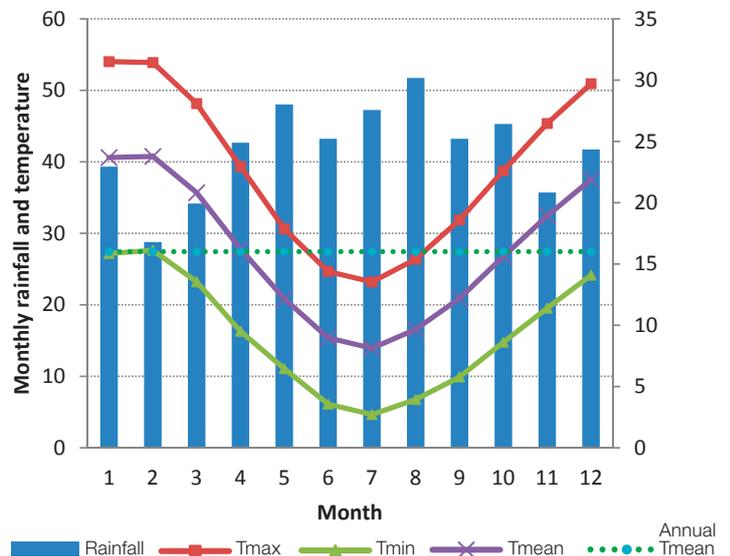


Figure 1: Seasonal rainfall and temperature variations (AWAP<sup>1</sup> data for 1960–1991).

1. Australian Water Availability Project, see [www.csiro.au/awap/](http://www.csiro.au/awap/).



## Rainfall

Rainfall varies considerably across the region. This variability is due to the complex interactions between weather patterns in the region such as the passage of cold fronts and low pressure systems, the influence of larger-scale climate patterns such as El Niño Southern Oscillation, the topography of the Snowy Mountains and Great Dividing Range and the reduced influence of coastal processes.

Rainfall varies considerably across the region with average annual rainfall ranging from 1600–2400 mm in the Snowy Mountains to 200–400 mm in the semi-arid plains in the west of the region. The South West Slopes receive an average annual rainfall in the range of 400–800 mm, with lower rainfall in the west and higher rainfall in the east towards the mountains.

Rainfall is relatively uniform throughout the year across much of the region, with marginally higher rainfall during winter and spring. The increase in winter and spring rainfall moving eastward through the South West Slopes and up into the Snowy Mountains, is typically due to the passage of frontal systems during these cooler months.

The region has experienced considerable rainfall variability in the past with periods of both wetter and drier conditions. During much of the first half of the 20<sup>th</sup> century the region experienced drier conditions. From the 1950s to the 1990s there was more inter-annual variability with many wet years and many dry years. The first decade of the 21<sup>st</sup> century saw a long period of below average rainfall during the Millennium Drought. This dry period ended with two of the wettest years on record for Australia (2010-2011), with 2010 being the third wettest year on record for NSW.

## Fire weather

The risk of bushfire in any given region depends on four ‘switches’. There needs to be enough vegetation (fuel), the fuel needs to be dry enough to burn, the weather needs to be favourable for fire to spread, and there needs to be an ignition source (Bradstock 2010). All four of these switches must be on for a fire to occur. The Forest Fire Danger Index (FFDI) is used in NSW to quantify fire weather. The FFDI combines observations of temperature, humidity and wind speed with an estimate of the fuel state.

Long-term observations of FFDI come from daily measurements of temperature, rainfall, humidity and wind speed at only a small number of weather stations in Australia, with 17 stations located in NSW and the ACT (Lucas 2010). Although these stations are spread fairly evenly across the state, there are no stations in alpine regions.

FFDI estimates are available for two stations in the region, Hay and Wagga Wagga. The average annual FFDI estimated for the period 1990–2009 was 9.4 at Hay and 10 at Wagga Wagga. The highest average FFDI occurs in summer and the lowest in winter.

Fire weather is classified as ‘severe’ when the FFDI is above 50, and most of the property loss from major fires in Australia has occurred when the FFDI reached this level (Blanchi et al. 2010). FFDI values below 12 indicate low to moderate fire weather, 12-25 high, 25-49 very high, 50-74 severe, 75-99 extreme and above 100 catastrophic.

Extreme fire weather conditions occur on average one day per year at Hay and five days per year at Wagga, and are more likely to occur in summer and spring months.

Average FFDI					
Station	Annual	Summer	Autumn	Winter	Spring
Hay	9.4	15.6	8.9	3.4	10.2
Wagga Wagga	10.0	19.4	10.0	2.2	8.6
Number of severe fire weather days (FFDI>50)					
Hay	1	0.35	0.05	0	0.6
Wagga Wagga	5.2	3.7	0.2	0	1.3

Table 1: Baseline FFDI values for meteorological stations within the Murray Murrumbidgee Region.

# Temperature

Climate change projections are presented for the near future (2030) and far future (2070), compared to the baseline climate (1990–2009). The projections are based on simulations from a suite of twelve climate models run to provide detailed future climate information for NSW and the ACT.

Temperature is the most reliable indicator of climate change. Across the Murray Murrumbidgee region all of the models agree that average, minimum and maximum temperatures are all increasing.

## Summary temperature

Maximum temperatures are projected to increase in the near future by 0.7°C

Maximum temperatures are projected to increase in the far future by 2°C

Minimum temperatures are projected to increase by near future by 0.6°C

Minimum temperatures are projected to increase by far future by 1.9°C

There are projected to be more hot days and fewer cold nights

## Projected regional climate changes

The Murray Murrumbidgee is expected to experience an **increase in all temperature variables** (average, maximum and minimum) for the near future and the far future (Figure 2).

Maximum temperatures are projected to increase by 0.7°C in the near future and by 2°C in the far future (Figure 2b). Spring and summer are projected to experience the greatest increases in maximum temperatures, increasing by 2.4°C in the far future. Increased maximum temperatures are known to impact human health through heat stress and increasing the numbers of heatwave events.

Minimum temperatures are projected to increase by 0.6°C in the near future and by 1.9°C in the far future (Figure 2c). Increased overnight temperatures (minimum temperatures) can have a considerable effect on human health.

These increases are projected to occur across the region (Figures 3–6).

The long-term temperature trend indicates that temperatures in the region have been increasing since approximately 1950, with the largest increase in temperature variables coming in the most recent decades.

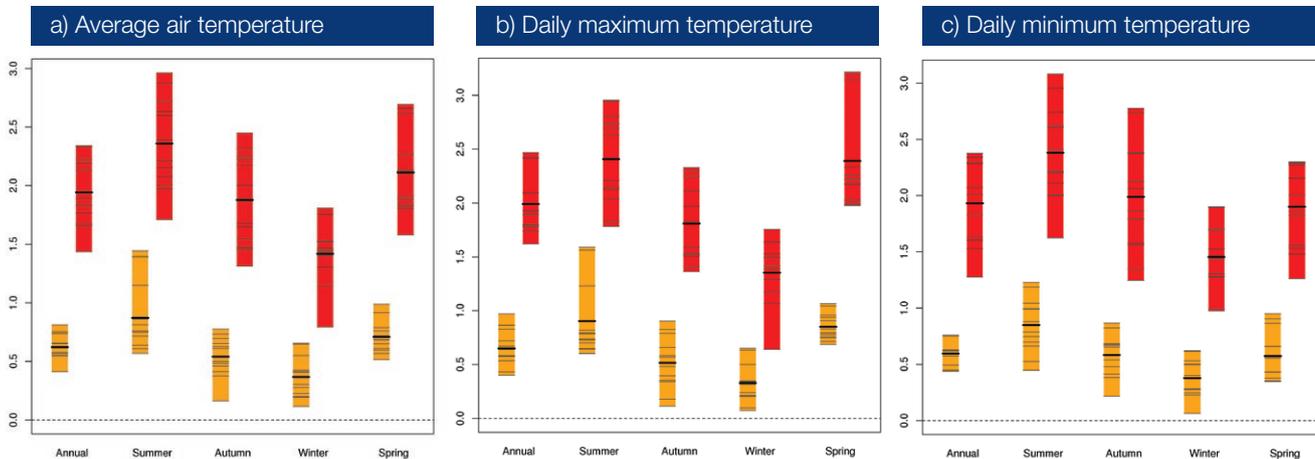


Figure 2: Projected air temperature changes for the Murray Murrumbidgee Region, annually and by season (2030 yellow; 2070 red): a) average, b) daily maximum, and c) daily minimum. (Appendix 1 provides help with how to read and interpret these graphs).

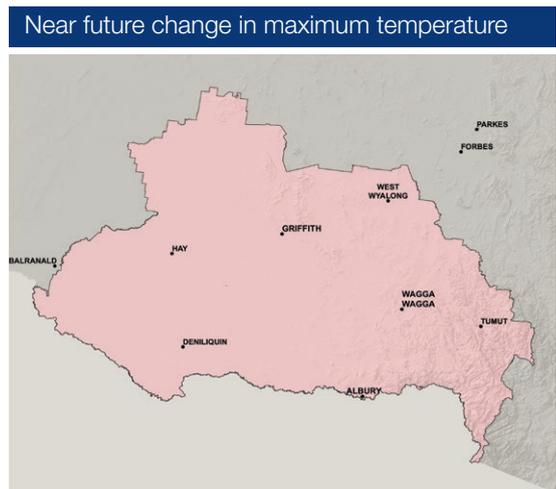


Figure 3: Near future (2020–2039) change in annual average maximum temperature, compared to the baseline period (1990–2009).

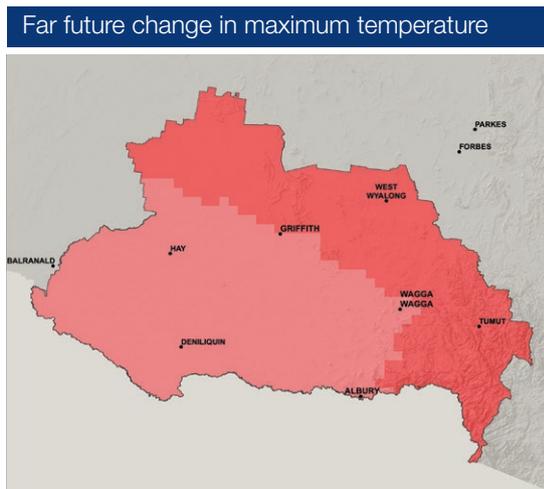


Figure 4: Far future (2060–2079) change in annual average maximum temperature, compared to the baseline period (1990–2009).

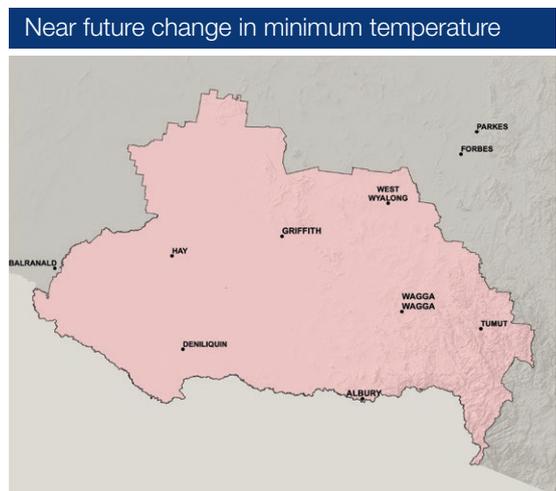


Figure 5: Near future (2020–2039) change in annual average minimum temperature, compared to the baseline period (1990–2009).

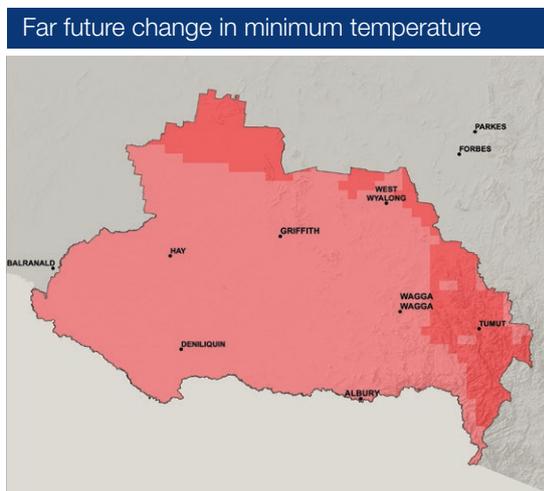
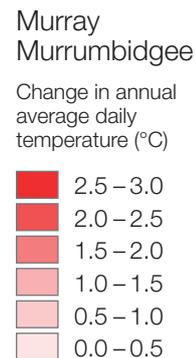


Figure 6: Far future (2060–2079) change in annual average minimum temperature, compared to the baseline period (1990–2009).



# Hot days

## DAYS PER YEAR ABOVE 35°C

Currently the Murray Murrumbidgee region experiences an average of over 40 hot days each year on the plains north of Hay, while in the Snowy Mountains there are very few days above 35°C. International and Australian experiences show that prolonged hot days increase the incidence of illness and death – particularly among vulnerable population groups such as people who are older, have a pre-existing medical condition or who have a disability. Seasonal changes are likely to have considerable impacts on bushfire danger, infrastructure development and native species diversity.

### Projected regional climate changes

**The Murray Murrumbidgee is expected to experience more hot days in the near future and the far future (Figure 7).**

**The greatest increase in hot days is projected for the plains north of Hay with an additional 10-20 hot days in the near future (Figure 8) and 30–40 more hot days per year by 2070 (Figure 9).**

**The region, on average, is projected to experience an additional eight hot days in the near future (5–13 days per year across the 12 models) and 23 more hot days in the far future (16-28 days per year across the 12 models) (Figure 7).**

**These increases are seen mainly in summer although in the far future hot days are also extending into spring and autumn (Figure 7).**

**There is little change in the number of hot days for the Snowy Mountains (Figures 8 and 9).**

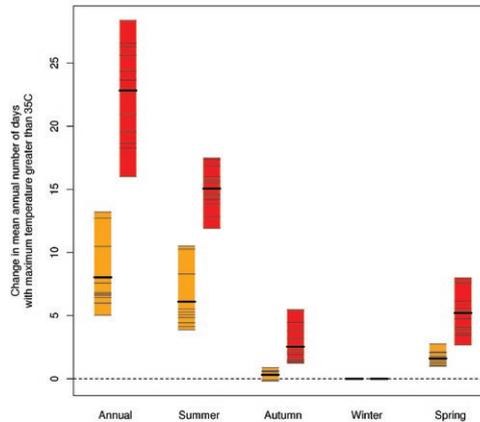


Figure 7: Projected changes in the number of hot days (with daily maximum temperature of above 35°C) for the Murray Murrumbidgee Region, annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read and interpret these graphs).

### Near future change in days per year above 35°C

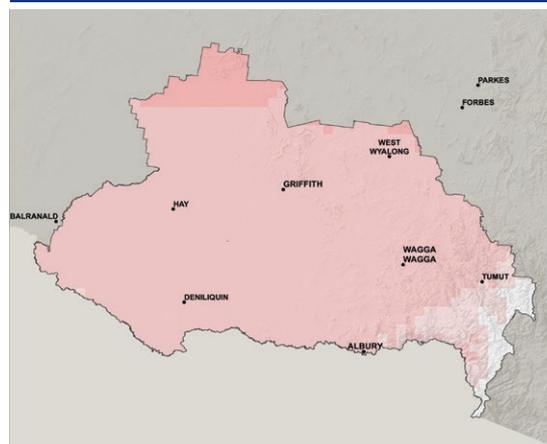
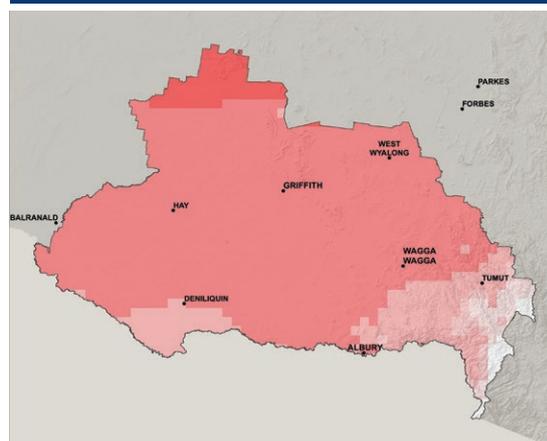


Figure 8: Near future (2020–2039) projected changes in the number of days per year with maximum temperatures above 35°C.

### Far future change in days per year above 35°C



### Murray Murrumbidgee

Change in annual average number of days with temperatures greater than 35°C

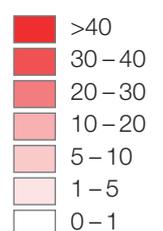


Figure 9: Far future (2060–2079) projected changes in the number of days per year with maximum temperatures above 35°C.

# Cold nights

## POTENTIAL FROST RISK

Most of the emphasis on changes in temperatures from climate change has been on hot days and maximum temperatures, but changes in cold nights are equally important in the maintenance of our natural ecosystems and agricultural/horticultural industries; for example, some common temperate fruit species require sufficiently cold winters to produce flower buds. The Snowy Mountains is also home to alpine ecosystems reliant on long cold periods and snow.

## Projected regional climate changes

The region is expected to experience fewer cold nights in the near future and the far future (Figure 10).

The greatest decreases are projected to occur in the mountains with 10-20 fewer cold nights in the near future and 20–30 fewer cold nights in the far future. All parts of the region are projected to have fewer cold nights (Figures 11 and 12).

All models agree there will be fewer cold nights with an average decrease across the region of approximately seven nights per year in the near future (ranging from 5–10 nights across the individual models). The decrease in cold nights is projected to be even greater in the far future, with an average decrease of 21 nights per year, ranging from 14–27 across the individual models (Figure 10).

A decrease in the number of cold nights is projected for all seasons with largest decreases in winter and spring (Figure 10).

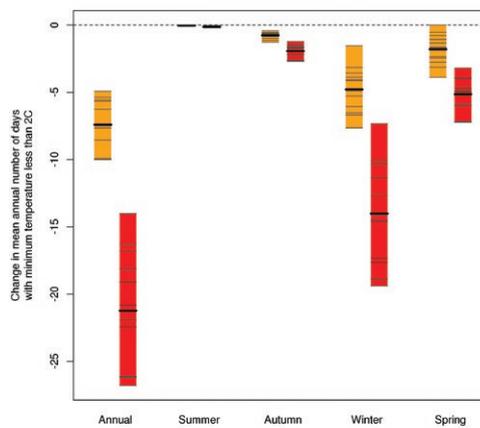


Figure 10: Projected changes in the number of low temperature nights for the Murray Murrumbidgee Region, annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read and interpret these graphs).

### Near future change in number of cold nights (below 2°C) per year

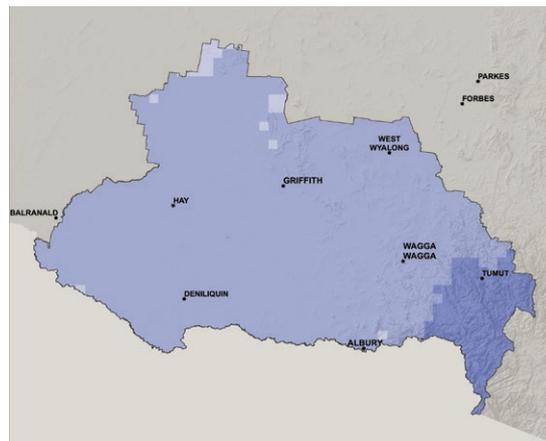


Figure 11: Near future (2020–2039) change in the number of days per year with minimum temperatures below 2°C, compared to the baseline period (1990–2009).

### Far future change in number of cold nights (below 2°C) per year

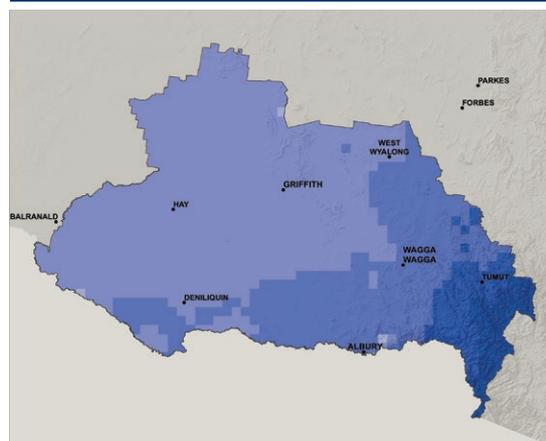
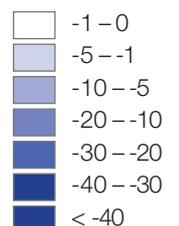


Figure 12: Far future (2060–2079) change in the number of days per year with minimum temperatures below 2°C, compared to the baseline period (1990–2009).

### Murray Murrumbidgee

Change in annual average number of days with temperatures less than 2°C



# Rainfall

Changes in rainfall patterns have the potential for widespread impacts. Seasonal shifts in rainfall can impact native species' reproductive cycles as well as impacting agricultural productivity; for example crops that are reliant on winter rains for peak growth.

Rainfall changes are also associated with changes in the extremes, such as floods and droughts, as well as secondary impacts such as water quality and soil erosion that occur as a result of changes to rainfall intensity.

Modelling rainfall is challenging due to the complexities of the weather systems that generate rain. 'Model agreement', that is the number of models that agree on the direction of change (increasing or decreasing rainfall) is used to determine the confidence in the projected change. The more models that agree, the greater the confidence in the direction of change.

Care should be taken when interpreting changes in rainfall from averaging climate change projections when the model outputs project changes of both wetting and drying. To understand the spread of potential changes in rainfall the bar charts should be considered along with the maps provided in this document.

## Rainfall is projected to decrease in spring and to increase in autumn

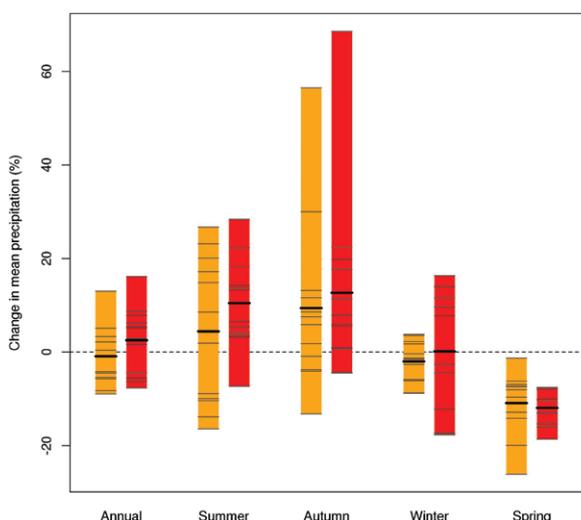


Figure 13: Projected changes in average rainfall for the Murray Murrumbidgee Region, annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read and interpret these graphs).

## Projected regional climate changes

**In the Murray Murrumbidgee Region all models agree that spring rainfall will decrease in both the near future and far future (Figure 13).**

**The majority of models (8 out of 12) agree that autumn rainfall will increase in the near future and the far future (10 out of 12) (Figure 13).**

Winter rainfall is projected to decrease by the majority of models (8 out of 12) in the near future. By 2070 projected changes in winter rainfall span both wetting and drying scenarios.

Summer rainfall is projected to increase by the majority of models in the near future (7 out of 12) and in the far future (11 out of 12) (Figure 13).

The entire region is projected to experience a reduction in rainfall in spring mainly along the Murray River by 2070 (Figures 14 and 15). Autumn increases are relatively uniform across the region.

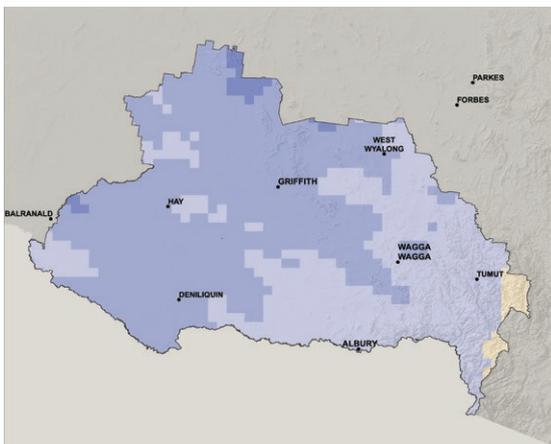
Seasonal rainfall projections for the near future and the far future span both drying and wetting scenarios for summer, autumn and winter. In the near future the projected changes are: summer -16% to +27%, autumn -13% to +57% and winter -9% to +4%. In the far future the projected changes are: summer -7% to +28%, autumn -5% to +69% and winter -18% to +16%.

Spring rainfall is projected to decrease by all models. The range of changes in spring rainfall are: -26% to -1% in the near future and -19% to -8% in the far future.

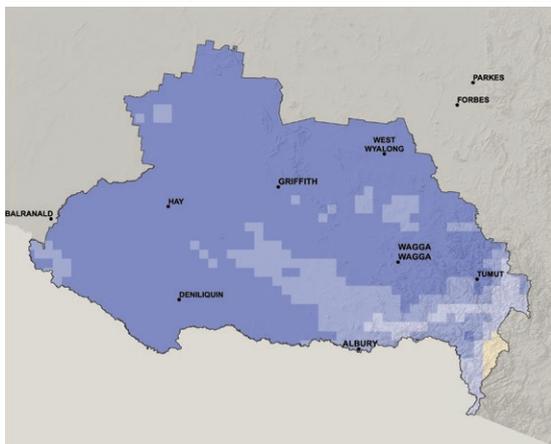
Annual rainfall projections also span both drying and wetting scenarios. The projected changes are: -9% to +13% in the near future and -8% to +16% in the far future.

The region currently experiences considerable rainfall variability across the region, seasons and from year-to-year and this variability is reflected in the projections.

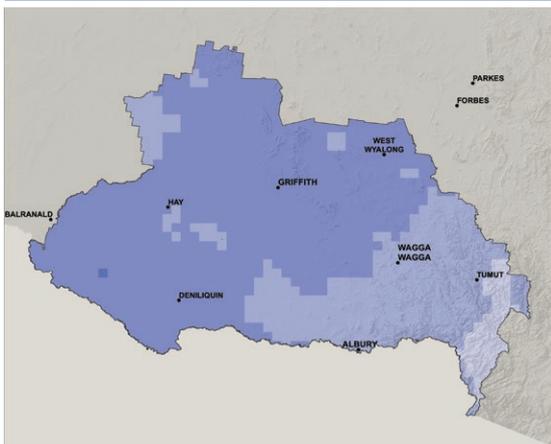
Summer 2020–2039



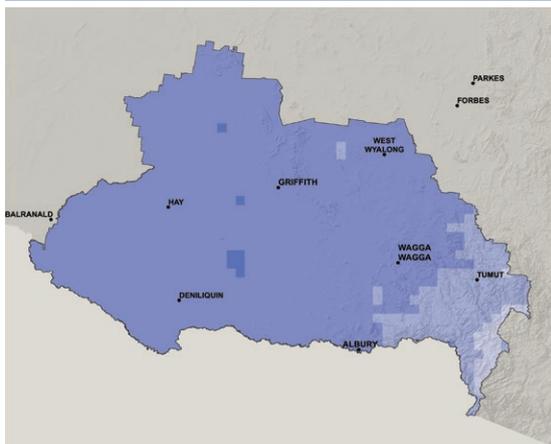
Summer 2060–2079



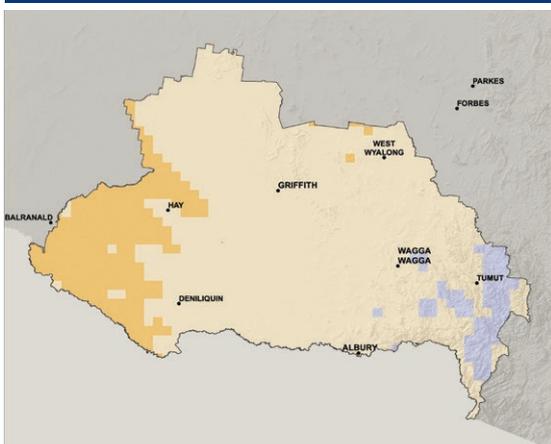
Autumn 2020–2039



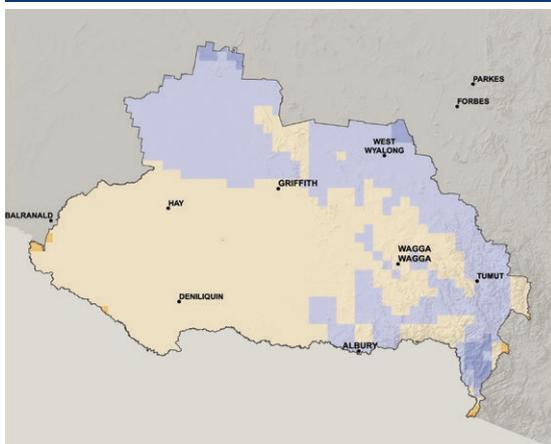
Autumn 2060–2079



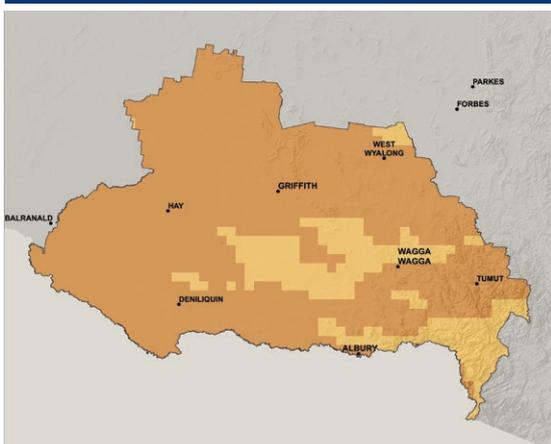
Winter 2020–2039



Winter 2060–2079



Spring 2020–2039



Spring 2060–2079

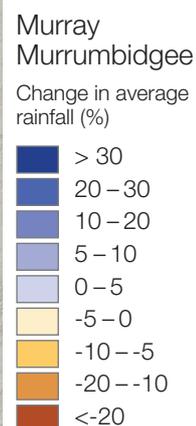
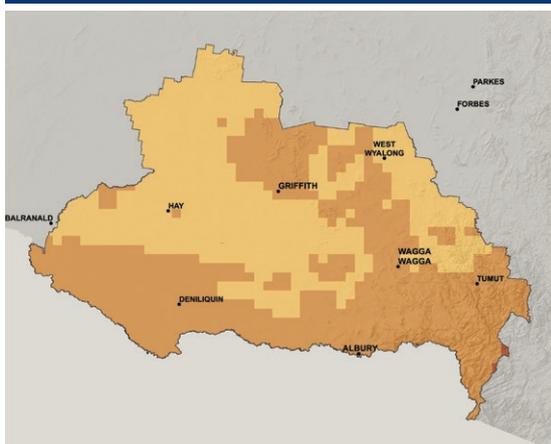


Figure 14: Near future (2020–2039) projected changes in average rainfall by season.

Figure 15: Far future (2060–2079) projected changes in average rainfall by season/

# Fire weather

The Bureau of Meteorology issues Fire Weather Warnings when the FFDI is forecast to be over 50. High FFDI values are also considered by the Rural Fire Service when declaring a Total Fire Ban.

Average FFDI values are often used to track the status of fire risk. These values can be used when planning for prescribed burns and help fire agencies to better understand the seasonal fire risk. The FFDI is also considered an indication of the consequences of a fire if one was to start – the higher the FFDI value the more dangerous the fire could be.

FFDI values below 12 indicate low to moderate fire weather, 12-25 high, 25-49 very high, 50-74 severe, 75-99 extreme and above 100 catastrophic.

## Severe and average FFDI is projected to increase

### Severe fire weather for the region in the near future is projected to decrease in autumn

## Projected regional climate changes

### The Murray Murrumbidgee region is projected to experience an increase in average and severe FFDI values in the near future and the far future (Figures 16 and 17).

Increases in severe and average fire weather are projected in summer and spring. The majority of models (9 out of 12) project an increase in severe fire weather during summer, and all models project an increase in spring by 2030 (Figure 17). This change is considerable given that summer and spring are considered peak fire danger seasons in NSW.

The greatest increases in severe fire weather is projected for the north-west of the region with 1.5–2 more severe fire weather days per year (Figure 19).

Autumn is projected to have a decrease in fire weather. As fire weather measurements take into account rainfall, it is likely that the decrease in autumn FFDI is due to projected increases in autumn rainfall across the region (compare Figures 14 and 15 with Figures 18 and 19).

By 2070 most models (11 out of 12) project increases in the average daily FFDI during summer and spring. The greatest increase during these seasons is projected to occur in the north-west of the region (Figure 16, 18 and 19).

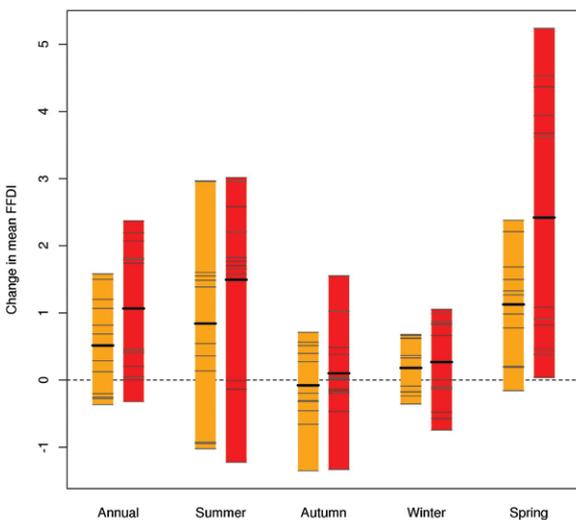


Figure 16: Projected changes in the average daily forest fire danger index (FFDI) for the Murray Murrumbidgee Region, annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read and interpret these graphs).

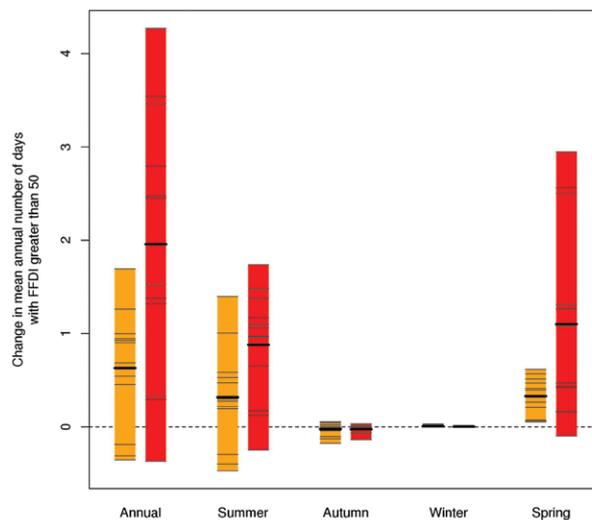
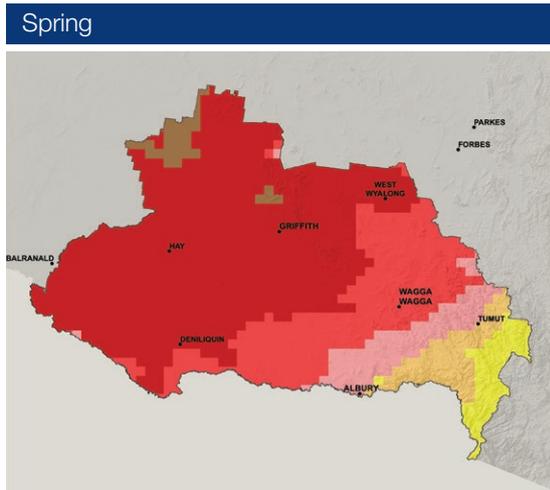
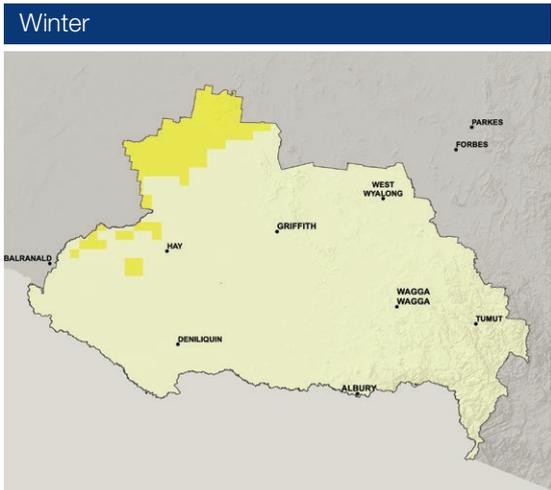
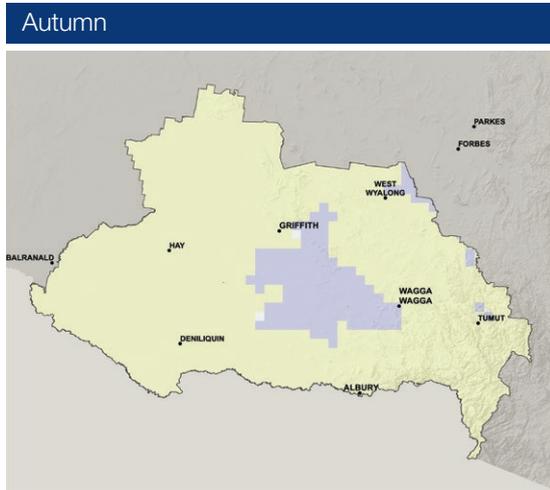
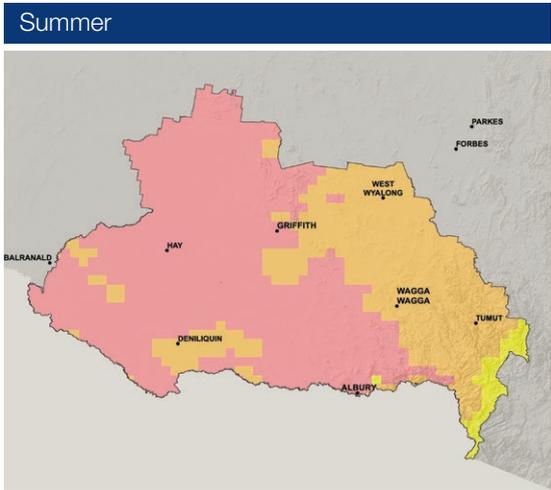


Figure 17: Projected changes in average annual number of days with a forest fire danger index (FFDI) greater than 50 for the Murray Murrumbidgee Region, annually and by season (2030 yellow; 2070 red). (Appendix 1 provides help with how to read and interpret these graphs).



Murray  
Murrumbidgee

Change in  
average FFDI

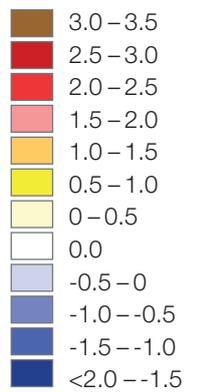
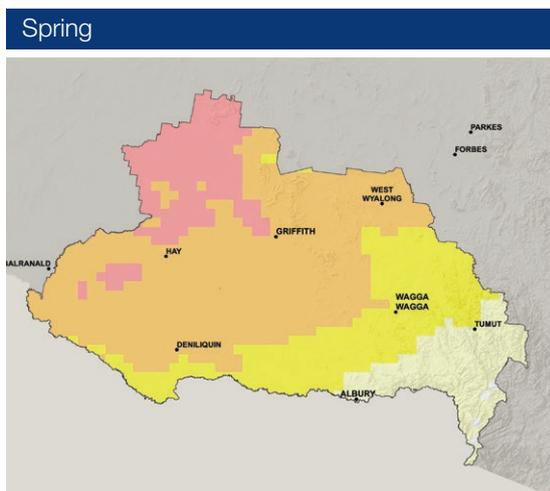
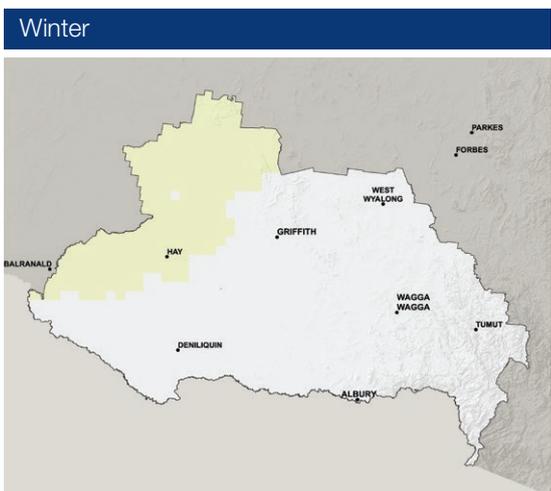
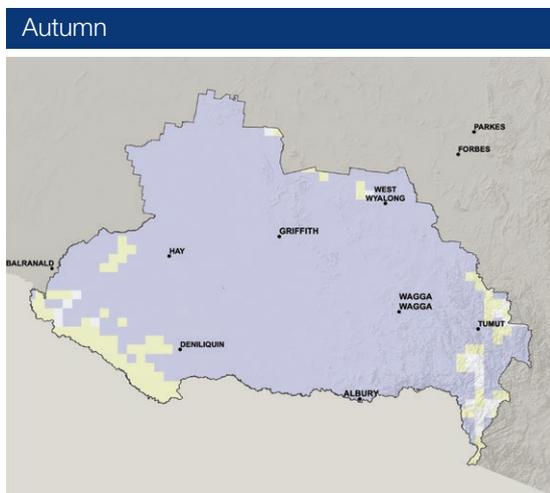
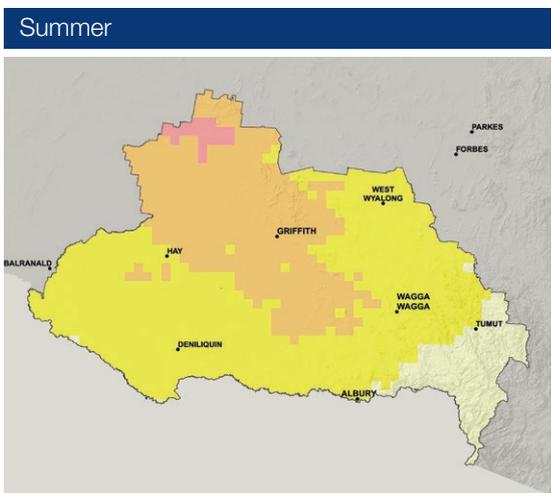


Figure 18: Far future (2060–2079) projected changes in average daily FFDI, compared to the baseline period (1990–2009).



Murray  
Murrumbidgee

Change in average  
number of days  
with FFDI greater  
than 50:

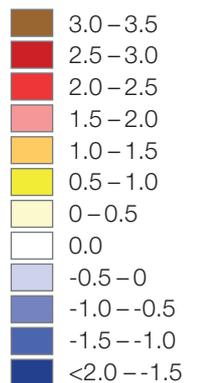


Figure 19: Far future (2060–2079) projected changes in average annual number of days with a FFDI greater than 50, compared to the baseline period (1990–2009).

## Appendix 1 Guide to reading the maps and graphs

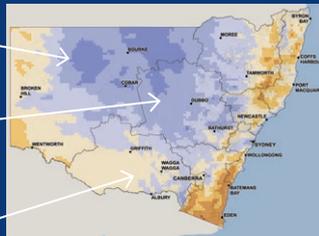
This document contains maps and bar graphs of the climate change projections. The maps present the results of the twelve models as an average of all twelve models. The bar graphs show projections averaged across the entire state and do not represent any particular location within the state. The bar graphs also show results from each individual model. See below for more information on what is displayed in the maps and bar graphs.

### How to read the maps

The maps display a **10km** grid.

NSW has been divided into State Planning Regions and each region has a Local Snapshot report.

The colour of each grid is the average of all **12** models outputs for that grid.



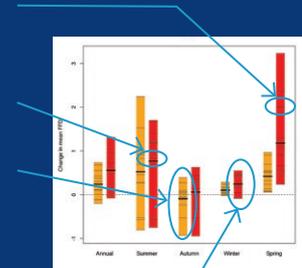
### How to read the bar graphs

The thin grey lines are the **individual models**. There are 12 thin lines for each bar.

The thick line is the **average of all 12 models** for the region.

The length of the bar shows the **spread of the 12 model values** for the region

Each line is the **average for the region**. They do not represent a single location in the region.



Note: The yellow bars represent near future scenarios (2020–2039), while the red bars represent far future scenarios (2060–2079).

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OEH 2014/0823 – 978 1 74359 833 7  
ISSN 1837–5650

November 2014

Printed on environmentally sustainable paper