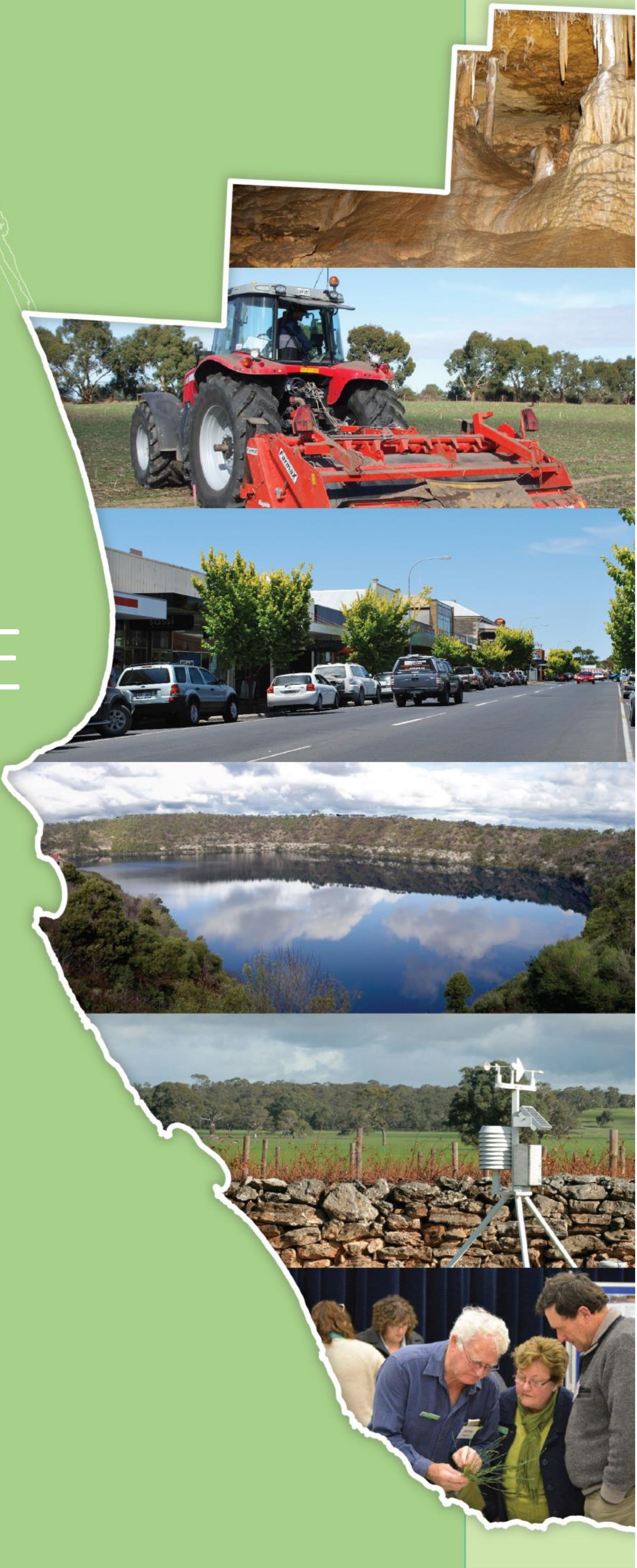
LIMESTONE COAST

REGIONAL CLIMATE CHANGE ADAPTATION PLAN PROJECT

CLIMATE PROJECTIONS REPORT



April 2015

Climate Projections Report

Limestone Coast Regional Climate Change Adaptation Plan Project

Lead Consultant	URPS
In association with	Seed Consulting Services
Prepared for	Regional Development Australia Limestone Coast, South East Local Government Association and the South East Natural Resources Management Board

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1. Summary of key points

- While there is natural variability in the climate of the Limestone Coast region, climate change will create a different future climate with warmer and drier conditions.
- Climate change planning uses climate projection data to assist with undertaking risk and vulnerability assessments and to assist with selecting adaptation options.
- The Project Steering Group for the Limestone Coast project has chosen to use projections for the Integrated Vulnerability Assessment based on median climate model outputs to 2070 under an intermediate (emissions) concentration pathway (RCP4.5).
- Median annual maximum temperature is projected to increase from baseline conditions by 1.1ºC by 2050 and 1.4ºC by 2070 under the intermediate concentration pathway, while extreme heat could increase from 21 days per year over 35 ºC to 31 days per year by 2070 under the intermediate concentration pathway.
- Rainfall is projected to decline by 4.8% and 6.8% compared with baseline conditions by 2050 and 2070, respectively, under the intermediate concentration pathway.
- Fire risk and extreme rainfall events are projected to increase in intensity in the coming century.
- Keith will experience a climate more similar to Kadina or Streaky Bay by 2090 under an intermediate concentration pathway and Mt Gambier will be more similar to Penola or Wangaratta under the same conditions.

2. Introduction

2.1 Limestone Coast overview

The Limestone Coast Regional Climate Change Integrated Vulnerability Assessment and Regional Adaptation Plan is a partner project between Regional Development Australia Limestone Coast, South East Local Government Association, South East Natural Resources Management Board, and the stakeholders and communities that live and work in the South East region of South Australia.

The project is being delivered through three main project phases:

- Preparing the evidence base - Identifying regional values with potential to be impacted by climate change, and gathering information to better understand these values and impacts;
- Undertaking the Integrated Vulnerability Assessment – Assessing the exposure, sensitivity, and adaptive capacity of the region to understand vulnerabilities in the face of climate change; and
- Preparing the Adaptation Plan – Identifying priority areas of focus for adaptation options and developing adaptation pathways maps.

2.2 Purpose of this report

Stage 2 of the project involves undertaking an Integrated Vulnerability Assessment (IVA) to identify areas which are vulnerable to the impacts of climate change. A key input to the IVA is the set of climate variables which are used in the assessment process.

Climate variables describe various aspects of the future climate such as:

- Maximum and minimum temperatures;
- Extreme heat;
- Quantity and seasonality of rainfall; and
- Number of extreme fire danger days.

Climate projection data is also used to inform identification of adaptation options and development of adaptation pathways which are key elements of the final Adaptation Plan.

This report has been prepared as an input to the IVA process and final Adaptation Plan and describes the drivers of climate change, sources of variation in climate projections and what climate the region may experience in the future.

3. Explaining climate change projection data

3.1 The Limestone Coast region

The Limestone Coast is located in the South East region of South Australia. The Region has a Mediterranean climate and as such experiences natural variability in weather during the year, characterised by hot dry summers and cold wet winters.

Climate patterns vary year to year as well with major climate influences including the[1]:

- El Niño Southern Oscillation (ENSO), the oscillation between El Niño and La Niña conditions which affects rainfall and temperature in eastern Australia; and
- Indian Ocean Dipole (IOD), which affects the climate of Australia and other countries that surround the Indian Ocean Basin, and is a significant contributor to rainfall variability.

The result of these and other climate influences are major variations in rainfall and temperature, especially drought cycles. In addition to this natural variability in climate, weather station data from across the region is showing longer term changes (trends) to rainfall, temperature and other variables attributed to climate change.

3.2 What is climate change?

Climate change is a consequence of the release of greenhouse gases like carbon dioxide, methane and nitrous oxide into the Earth's atmosphere. These gases are produced from a range of natural sources as well as from human activities like energy production, transport, industrial processing, waste management, agriculture and land management. Greenhouse gases trap the Sun's energy in the Earth's atmosphere leading to changes in the global climate.

The most authoritative source of information on climate change is the Intergovernmental Panel on Climate Change (IPCC). Every 5-6 years the IPCC produces an Assessment Report which presents the most up to date summary of the current state of climate change science. Climate change modelling conducted for these assessments is used to inform further modelling across the world to support regional climate change planning.

The most recent report, Assessment Report 5 (AR5) was released in September 2013. An overview of some of the main conclusions of AR5 are outlined in Box 1.

[1] http://www.bom.gov.au/climate/enso/history/ln-2010-12/IOD-what.shtml. Accessed 27 October 2014.

Box 1: What is the evidence that the Earth's climate is changing?[2]

The Intergovernmental Panel on Climate Change (IPCC) is the world's leading international body for the assessment of climate change. The IPCC releases an assessment of the state of scientific knowledge relevant to climate change about every 6 years. Working Group I of the IPCC released its part of the Fifth Assessment Report in September 2013 and made the following conclusions that are relevant to adaptation planning:

- Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the sea level has risen, and the concentrations of greenhouse gases have increased;
- Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 when detailed temperature records began;
- Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010;
- The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia. Over the period 1901 to 2010, global mean sea level rose by 0.19 m;
- The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years;
- Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system; and
- Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

Two major climate change projections projects contain information relevant to the Limestone Coast region which draw on the suite of climate models used for AR5.

The Goyder Institute's "Agreed downscaled climate projections for South Australia" project, called SA Climate Ready provides (a) detailed weather station downscaled data for temperature, rainfall, solar radiation, vapour pressure deficit and areal evapotranspiration and (b) region scale trend data for temperature and rainfall for NRM regions[3].

[2] Intergovernmental Panel on Climate Change (2013*). Summary for Policymakers*. In: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[3] Detailed data is available from EnviroDataSA and region scale summaries are available from www.goyderinstitute.org.au

The CSIRO and Bureau of Meteorology project “Climate Change in Australia: Projections for Australia’s NRM regions” (CCIA) provides projected climate change data for the following variables at various temporal and spatial scales: temperature, rainfall, relative humidity, point potential evapotranspiration, wet areal evapotranspiration, wind-speed, solar radiation, wind speed, fire weather days, mean and extreme sea-level rise, sea surface temperature, sea surface salinity and ocean acidification. The Limestone Coast is part of the Murray Basin cluster, which mainly covers NRM regions across the southern part of the Murray-Darling Basin. The South Australian Murray-Darling Basin is the only other NRM region in South Australia that is part of this cluster.

3.3 Sources of variation in projections

It is not possible to “predict” or “forecast” what the future climate might be. Instead, climate models use emission and land use scenarios to develop “projections” that can be used to explore what future conditions may look like.

There is variability between projections and an understanding of the reason behind the variability is needed to assist with determining how best to use climate data in adaptation planning.

Climate projections vary in two main ways as follows.

1. Global climate models

Global climate models (GCMs)[4] are numerical models that explore how physical processes in the atmosphere, ocean, cryosphere and land surface respond to increasing greenhouse gas concentrations. GCMs are used to generate projections for climate variables like temperature and rainfall.

A large number of GCMs exist (over 40), however, only a subset are generally used to project the climate for a given location or region. For example, the SA Climate Ready project used 15 GCMs to generate climate projections and refined this to a list of the “best” six based on the ability of the GCMs to reproduce the effects of drivers such as the Indian Ocean Dipole and the El Niño Southern Oscillation.

The CCIA project provides summary information and projected change data using up to 40 GCMs. The number of models vary dependent on the climate variable and concentration pathway of interest, at the resolution of the particular host GCM (~67km to ~333km).

Variability exists across the outputs of GCMs and hence projections are often described for the median (50th percentile) model (GCM) output, sometimes described as the best estimate, or the 10th and 90th percentile output.

GCMs can also vary in terms how they represent the sensitivity of the global climate to increasing greenhouse gas emissions, with greater sensitivity resulting in a more rapid increase in temperature per unit increase in greenhouse gas concentrations[5].

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[4] Often interchangeably referred to as general circulation models

[5] Sinclair Knight Merz (SKM) (2013) *Western Adelaide Region Climate Change Adaptation Plan – Stage 1*, City of Port Adelaide Enfield

2. Representative Concentration Pathways

Representative Concentration Pathways, are scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use and land cover[6]. Previous IPCC reports referred to the Special Report on Emissions Scenarios (SRES) group of emission scenario descriptions and adaptation planning in Australia typically focused on low (B1), medium (A1B) and high (A1FI) SRES scenarios.

In the IPCC's recent AR5, four representative concentration pathways ("RCPs") were selected from the published literature and are used as a basis for the climate projections presented in AR5 based modelling as follows[7]:

- RCP 2.5 "Peak and decline scenario" – An emission pathway leading to very low greenhouse gas concentration levels; a so-called "peak" scenario (radiative forcing[8] peaks at approximately 3 W per m2 before 2100 and then declines);
- RCP 4.5 "Intermediate, stabilisation scenario" - An emissions pathway where the impact of climate change on the atmosphere is stabilised before 2100 by using a range of technologies and strategies for reducing greenhouse gas emissions (radiative forcing is stabilised at approximately 4.5 W per m2 after 2100);
- RCP 6.0 "Intermediate, stabilisation scenario" – An emissions pathway where the impact of climate change on the atmosphere is stabilised after 2100 by using a range of technologies and strategies for reducing greenhouse gas emissions (radiative forcing is stabilised at approximately 6.0 W per m2 after 2100); and

  RCP 8.5 "High emissions scenario" – An emissions pathway characterized by increasing greenhouse gas emissions over time leading to high greenhouse gas concentration levels.

Projections of emissions from fossil fuels and cement for the four RCPs is presented in Figure 1, noting that emissions are currently tracking on the high concentration pathway.

Another source of variability in relation to emission scenarios is the timeframe. Scenarios are often considered for 2030, 2050, 2070 or 2090 timeframes[9], with the concentration of greenhouse gases in many cases increasing through time, hence increasing the extent of, for example, warming.

[6] IPCC, 2013: Annex III: Glossary [Planton, S. (ed.)]. In: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[7] Descriptions are based on http://tntcat.iiasa.ac.at:8787/RcpDb/dsd?Action=htmlpage&page=welcome

[8] Radiative forcing is the extra heat the lower atmosphere will retain as a result of additional greenhouse gases, measured in Watts per m². http://www.cawcr.gov.au/publications/otherreports/ACCSP_RCP.pdf

[9] Unless stated otherwise projection timeframes are based on multi decadal averages, for example, 2050 represents the average of data for the period 2040 – 2059.

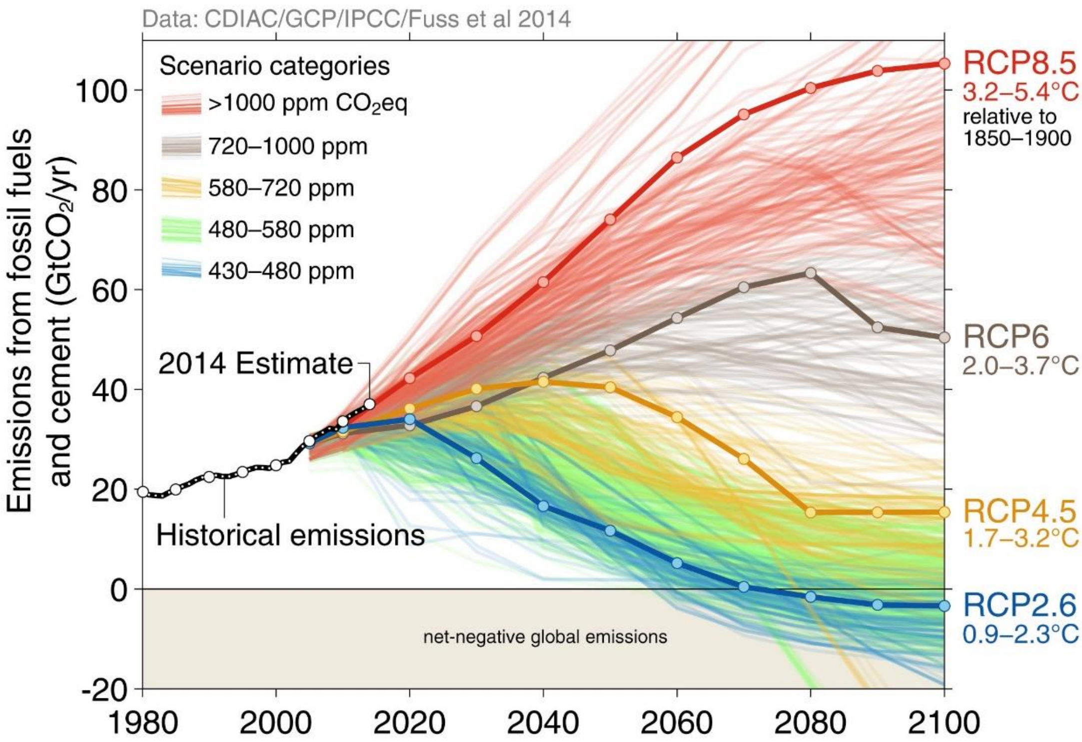

Figure 1 Emissions from fossil fuels and cement production for four RCPs. The historical emissions line is showing to be tracking along RCP8.5[10]

[10] Global Carbon Project (2014). *Global Carbon Budget 2014*. http://www.globalcarbonproject.org/carbonbudget/index.htm. Accessed: 3 February 2015.

4. How will climate change affect the Region?

4.1 Selecting a projection to use for the Region's IVA

As described in Section 3.3, climate change projections can vary for a number of reasons. However, for the purpose of conducting an IVA, it is not practical or necessary to run the IVA with multiple projections.

The Project Steering Group considered the range of projections that could be used and agreed to base the IVA on data from the median model output, with a timeframe of 2070 and using an intermediate concentration pathway. It should be noted that there are two intermediate concentration pathways that have been prepared by the IPCC (see Section 3.3). Data for RCP4.5 are presented here because of its greater availability from the SA Climate Ready and Climate Change in Australia projects than RCP6.0. In doing so it should be noted that there are substantial differences in the potential outcomes of RCPs4.5 and 6.0 in terms of greenhouse gas concentrations in the atmosphere by the end of the century (i.e. 850 versus 650 ppm CO2 equivalent concentrations by 2100, respectively). The decision of 2070 as a timeframe reflects that many of the decisions made by the private and public sector, whether planning or infrastructure based, have a timeframe of several decades or more.

The median temperature and rainfall data presented in Section 4.2 is based on the SA Climate Ready information , which is from the average change across 24 weather stations from the South East NRM region[11]. However, projections are not currently available from SA Climate Ready for rainfall intensity, extreme heat, fire risk, sea level rise, sea surface temperature and ocean pH and so this data is based on the CCIA project results and other sources.

Data to 2070 is not available at this stage from SA Climate Ready or Climate Change in Australia for fire risk, sea level rise, ocean pH and sea surface temperature and so is presented for 2030 and 2090.

4.2 Climate projections for the Limestone Coast region

Data described in this Section is based on either the median or average of model results. Further details about ranges are contained in source documents.

Rainfall

By 2050, the SA Climate Ready data suggests that annual median rainfall will decline by 4.8% and 7.9% compared with the baseline[12] under the intermediate and high concentration pathways, respectively (Figure 2). By 2070, the rainfall decline for the intermediate pathway is 6.8% compared with 11.1% for the high concentration pathway.

The seasonal differences in rainfall change are significant. By 2050, declines in winter and autumn rainfall are less than 6% for intermediate and high concentration pathways, whereas spring rainfall declines are at least17% (Figure 3). The emphasis on declining spring rainfall is also dominant by 2070, with declines of 20.5% and 27.6% projected under intermediate and high concentration pathways, respectively (Figure 4).

[11] A list of weather stations for the South East region is contained in the SA Climate Ready User Guide, available on https://data.environment.sa.gov.au/Climate/Pages/Home.aspx
[12] The baseline period for the SA Climate Ready data is 1986-2005.

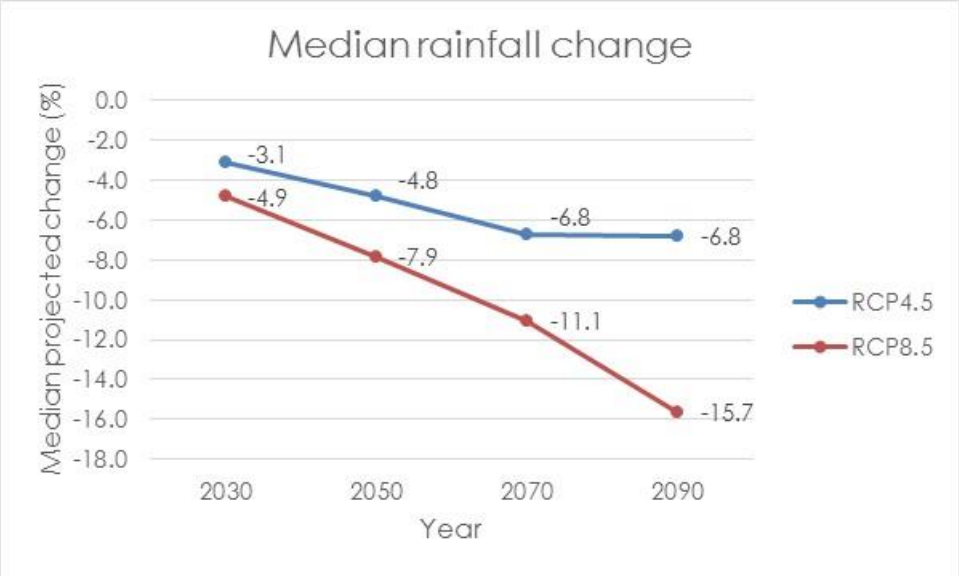

Figure 2 Projected change in median rainfall below the baseline period for 2030 to 2090 for the intermediate and high concentration pathways[13]

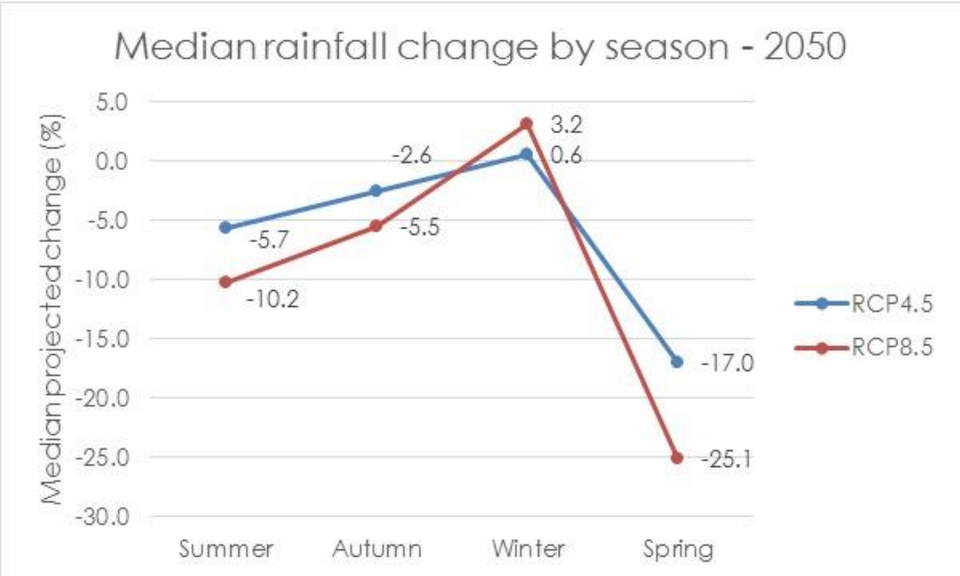

Figure 3 Projected change in median rainfall for each season below the baseline period in 2050 for the intermediate and high concentration pathways[14]

[13] Charles, S.P. and Fu G. (2014). *Statistically Downscaled Projections for South Australia* – Task 3 CSIRO Final Report, Goyder Institute for Water Research Technical Report Series, Adelaide, South Australia.
[14] Charles, S.P. and Fu G. (2014).

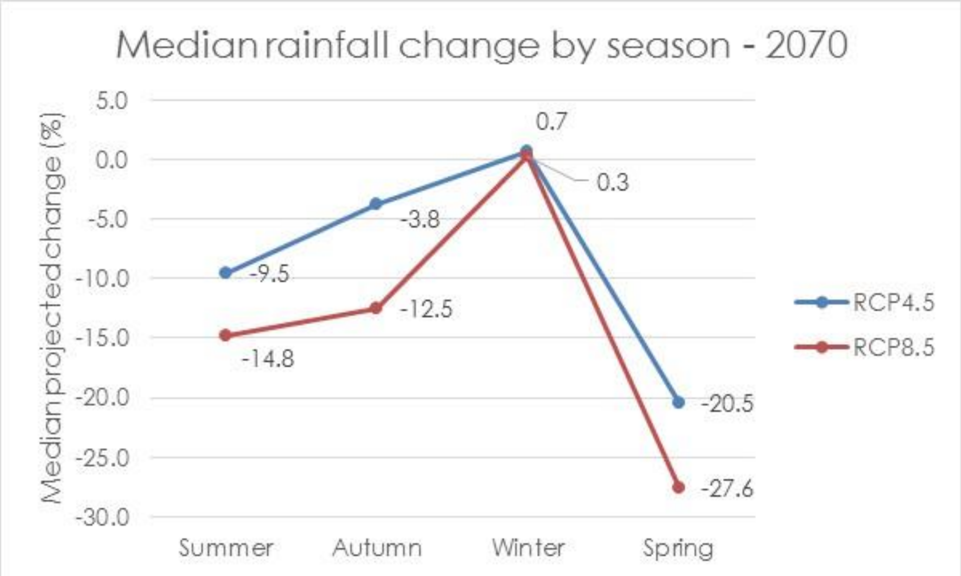

Figure 4 Projected change in median rainfall for each season below the baseline period in 2070 for the intermediate and high concentration pathways[15]

Rainfall intensity

The CCIA project results suggest that while median annual rainfall is tending towards a decrease, the extremes are projected to increase. There is high confidence that the intensity of daily rainfall events will increase, however, there is low confidence in the magnitude of change, and thus the time when any change may be evident against natural fluctuations[16].

Data for the Murray Basin cluster as a whole suggest that annual maximum 1-day precipitation compared to baseline conditions (1986-2005) could increase by 7% and 6% by 2050 under an intermediate and high concentration pathway and 5% and 15% by 2070 under an intermediate and high concentration pathway.

Other analysis suggests that for each degree of global warming, extreme daily rainfall may increase by 7%[17]. If this was to apply in the Limestone Coast region, increasing temperatures could be expected to increase rainfall intensity by nearly 7% in the region by 2030 and at least 14% by 2070 under a high concentration pathway.

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[15] Charles, S.P. and Fu G. (2014).

[16] Timbal, B. et al. 2015, *Murray Basin Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports*, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia

[17] Westra, S., Alexander, L. V., & Zwiers, F. W. (2012). *Global increasing trends in annual maximum daily precipitation*. Journal of Climate Change, 26, 3904-3918

Temperature

Surface air temperatures in the region have warmed since national records began in 1910, especially since 1960[18]. According to the CCIA project, from 1910 to 2013 mean temperature across the Murray Basin have risen by 0.8 °C (daytime maximum temperature rise of 0.7 °C, overnight minimum temperatures rise of 1.0 °C). This can be compared with local data for Robe, which shows a similar magnitude change (Figure 5).

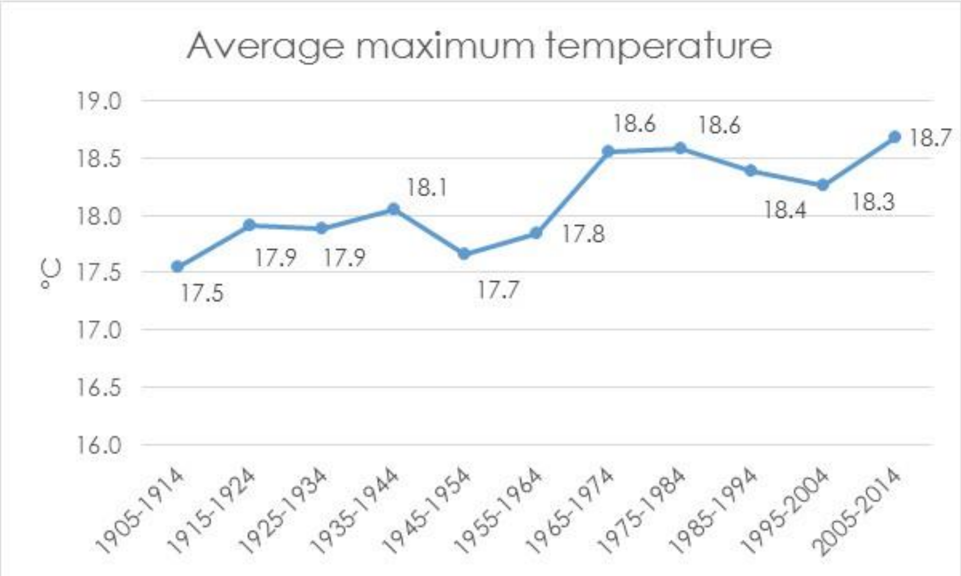

Figure 5: Average decadal maximum temperatures at Robe, South Australia. (Source: Bureau of Meteorology)

By 2050, the SA Climate Ready data suggests that annual median maximum temperature will increase compared to the baseline by 1.1°C and 1.4°C under the intermediate and high concentration pathways, respectively (Figure 6). By 2070, the increase in maximum temperature for the intermediate concentration pathway is 1.4°C compared with 2.1 °C for the high concentration pathway.

The difference between seasons in maximum temperature by 2070 is limited, with summer-autumn-winter projected to increase by 1.2-1.3°C compared to 1.6°C for spring under the intermediate concentration pathway. A similar difference exists under the high concentration pathway with a projected summer-autumn-winter increase of 2.0-2.2°C compared with 2.4°C for spring.

[18] Timbal et al. (2015)

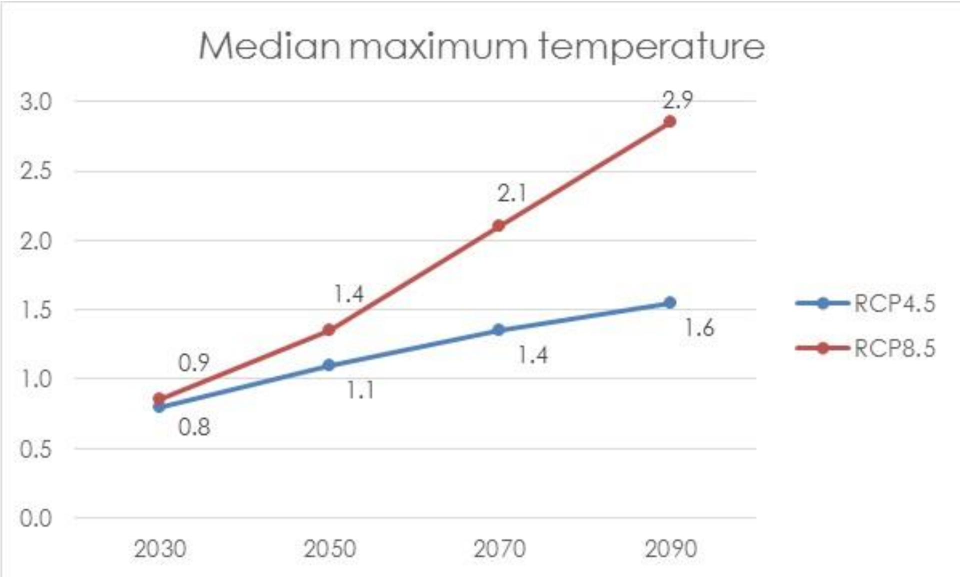

Figure 6: Median maximum temperature rise for the South East NRM region above the baseline period for 2030 to 2090 for the intermediate and high concentration pathways[19]

Minimum median temperatures show a similar trend to maximums, suggesting an increase compared to the baseline by 2050 of 0.9°C and 1.3°C under the intermediate and high concentration pathways, respectively (Figure 7). By 2070, the increase in minimum temperature for the intermediate pathway is 1.1°C compared with 1.9°C for the high concentration pathway.

The difference between seasonal changes in minimum temperature by 2070 is limited, with all seasons projected to increase by 1.0 to 1.2°C under an intermediate concentration pathway. Under the high concentration pathway the summer, winter and spring increase by 1.8°C and autumn by 2.1°C.

[19] Charles, S.P. and Fu G. (2014).

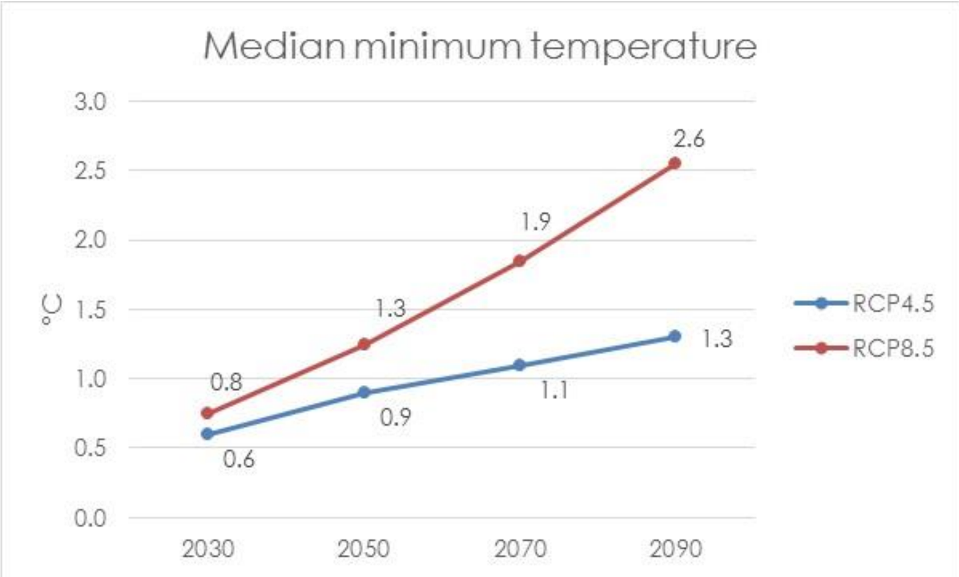

Figure 7: Median minimum temperature rise above the baseline period for the South East NRM region above the baseline period for 2030 to 2090 for the intermediate and high concentration pathways[20]

Heat extremes

The CCIA website enables users to assess the number of days on average that temperatures exceed threshold levels for a given year, concentration pathway and GCM. Results for the following nine GCMs are available: ACCESS1.0; CESM1-CAM5; CNRM-CM5; CanESM2; GFDL-ESM2M; HadGEM2-CC; MIROC5; and NorESM1-M. Median results for the 9 models are presented in Table 1 for the average number of days above 35°C and 40°C by 2050 and 2070 under an intermediate and high concentration pathway for Keith and Mt Gambier.

At Keith by 2050, the number of days over 35°C is projected to increase by 33 to 50% under intermediate and high concentration pathways respectively, and by 2070 by 48 to 76%. A greater increase occurs for days over 40°C, with an 88 to 125% increase by 2050 under an intermediate and high concentration pathway and 113 to163% by 2070.

At Mt Gambier, the increase is marginally greater than for Keith. By 2050, the number of days exceeding 35ºC will increase by 50 to 75% compared to the baseline and by 2070 will increase by 75 to 117%. In contrast, the number of days exceeding 40°C will double by 2050 and increase by 100-200% by 2070, under intermediate and high concentration pathways, respectively.

[20] Charles, S.P. and Fu G. (2014).

Table 1 shows the change in the average number of days per year over 35°C and 40°C at Keith and Mt Gambier to 2050 and 2070. Projected changes are from a historical baseline of 1981-2010. The 2050 data is an average for the period 2036-2065 and 2070 is an average for the period 2056-2085[21].

Table 1 Change in the average number of days per year over 35°C and 40°C at Keith and Mt Gambier

KEITH					
Avg. days per year >35ºC	**Historical**	**Median**	**% Δ from historical**	**10th percentile**	**90th percentile**
RCP4.5, 2050	21	28	33%	26.7	31.2
RCP8.5, 2050	21	31.5	50%	28.7	35.9
RCP4.5, 2070	21	31	48%	29	34.3
RCP8.5, 2070	21	37	76%	33	43.9
Avg. days per year >40ºC	**Historical**	**Median**	**% Δ from historical**	**10th percentile**	**90th percentile**
RCP4.5, 2050	4	7.5	88%	7	8.6
RCP8.5, 2050	4	9	125%	7.7	10.6
RCP4.5, 2070	4	8.5	113%	7.7	10
RCP8.5, 2070	4	10.5	163%	9	15.3
MOUNT GAMBIER					
Avg. days per year >35ºC	**Historical**	**Median**	**% Δ from historical**	**10th percentile**	**90th percentile**
RCP4.5, 2050	6	9	50%	8.7	10
RCP8.5, 2050	6	10.5	75%	9	11.6
RCP4.5, 2070	6	10.5	75%	9	11.3
RCP8.5, 2070	6	13	117%	11	14.6
Avg. days per year >40ºC	**Historical**	**Median**	**% Δ from historical**	**10th percentile**	**90th percentile**
RCP4.5, 2050	1	2	100%	1	2
RCP8.5, 2050	1	2	100%	1.7	2.3
RCP4.5, 2070	1	2	100%	1	2.3
RCP8.5, 2070	1	3	200%	2	3.3

[21] Clarke et al. (2011) '*Providing Application-specific Climate Projections Datasets: CSIRO's Climate Futures Framework*.' Peer-reviewed conference paper. In F Chan, D Marinova and RS Anderssen (eds.) MODSIM2011, 19th International Congress on Modelling and Simulation. Perth, Western Australia. December 2011 pp. 2683-2690. ISBN: 2978-2680-9872143-9872141-9872147. (Modelling and Simulation Society of Australia and New Zealand). http://www.mssanz.org.au/modsim2011/F5/clarke.pdf

Fire risk

Fire weather projections were estimated in the CCIA project using the McArthur Forest Fire Danger Index (FFDI). Fire weather is considered 'severe' when the FFDI exceeds 50 and extreme when FFDI exceeds 75. The Murray Basin cluster analysis was undertaken for four stations, which included Mt Gambier.

The CCIA projections suggest an increased fire weather risk in the future for Mt Gambier. General fire weather danger increases by about 9-11% by 2030 (for both concentration pathways), 15 % under RCP4.5 by 2090, and 29 % under RCP8.5 by 2090[22] (Table 2). The number of days per year with a 'severe' fire danger rating increases by 19-27% by 2030, and from 36% (RCP4.5) to 55% (RCP8.5) by 2090. The sum of all daily FFDI over a year provides an indication of general fire weather risk and this figure is also projected to increase (Table 2).

Table 2. Summary of fire risk statistics for Mt Gambier based on outputs from the CCIA project. %Δ represents the percentage change from the 1995 baseline data[23]

	Severe fire risk days (days per year)	%Δ	Forest Fire Danger Index	%Δ
1995 Baseline	1.6		2026	
2030 RCP4.5	2.2 (1.9 to 2.8)	27%	2284 (2105 to 2613)	11%
2030 RCP8.5	2 (1.8 to 2.3)	19%	2215 (2157 to 2281)	9%
2090 RCP4.5	2.5 (2.1 to 2.8)	36%	2379 (2301 to 2423)	15%
2090 RCP8.5	3.6 (2.4 to 4.4)	55%	2845 (2161 to 3475)	29%

Sea level rise

Rising sea levels will occur as a result of thermal expansion of the oceans as they warm and additional water will enter the world's oceans from melting ice. Global sea levels have been observed to have risen by about 21 cm from 1880 to 2009, primarily as a result of thermal expansion[24]. Over the period 1966–2009, sea levels have risen around the Australian coastline at an average rate of 2.1 mm/yr and 3.1 mm/yr over 1993–2009[25]. (This rate allows for removal of the influence of the El Niño Southern Oscillation and the effects of vertical land movements due to glacial rebound and the effects of natural climate variability and changes in atmospheric pressure.)

Projections of global mean sea level rise at Victor Harbor suggest an increase of 11-13 cm by 2030 and 30-40 cm by 2070 (Table 3). By the end of the century sea levels are expected to rise by approximately 0.5 m under an intermediate concentration pathway. Victor Harbor is the closet tide gauge to the Murray Basin cluster coast and is noted to be indicative of the coast line to Portland. Portland in the adjacent climate cluster is included in the Climate Change in Australia project[26] and shows almost identical projections for sea level rise.

[22] Timbal et al. (2015)
[23] Timbal et al. (2015)
[24] http://www.cmar.csiro.au/sealevel/sl_impacts_sea_level.html. Accessed 1 September 2014
[25] CSIRO and Bureau of Meteorology, Climate Change in Australia website, cited 13 April 2015.
[26] CSIRO and BoM (2015)

Table 3. Median values and likely ranges for projections of regional sea level rise (in metres) relative to 1986 - 2005 under all RCP scenarios for Victor Harbour[27].

	2030	2050	2070	2090
RCP2.6	0.12 (0.07-0.16)	0.21 (0.13-0.28)	0.30 (0.18-0.42)	0.38 (0.23-0.55)
RCP4.5	0.12 (0.08-0.16)	0.22(0.14-0.30)	0.33 (0.21-0.46)	0.45 (0.28-0.63)
RCP6.0	0.11 (0.07-0.16)	0.21 (0.13-0.29)	0.32 (0.20-0.45)	0.46 (0.28-0.64)
RCP8.5	0.13 (0.08-0.17)	0.24 (0.16-0.33)	0.40 (0.26-0.55)	0.60 (0.39-0.83

Sea surface temperatures

The world's oceans will continue to warm in the coming century as they absorb heat from the atmosphere. By 2030 warming of the ocean could result in a 0.5ºC increase in sea surface temperatures in the nearby ocean and a 1.2 to 2.2ºC rise by 2090, under the intermediate and high concentration pathway respectively[28].

Ocean pH

The IPCC's AR5 suggests that the Earth's oceans will become more acidic (pH units decrease from the usual slightly alkaline values of 7.5 to 8.0 towards more neutral levels at pH =7) under all scenarios assessed. Projections for decreasing pH at Victor Harbour range from 0.07 to 0.08 by 2030 under the intermediate and high concentration pathway, respectively, and 0.15-0.32 by 2090. This compares with a 0.1 pH unit decrease that has already been experienced since the beginning of the industrial era about 250 years ago[29].

4.3 Climate analogues

The Climate Analogues tool on the Climate Change in Australia website provides an ability to match the projected future climate of a location with the current climate experienced in another location using annual average rainfall and maximum temperature. The tool was applied to the Limestone Coast region (Table 4) using the maximum consensus model outputs.

Under this setting, Keith will experience a climate more similar to Streaky Bay and Kadina by 2050 (RCP8.5) while Mt Gambier will experience a climate more similar to Penola (RCP8.5). By 2090, Keith will be more similar to Cobar and Walgett in western NSW and Mt Gambier will be more similar to Perth.

[27] Table 8.12, CSIRO and BoM (2015)
[28] Timbal et al. (2015)
[29] Timbal et al. (2015)

Table 4. Climate analogue analysis results for Keith and Mt Gambier[30].

Town	Projection	Analogue towns	Data
Keith	RCP4.5, 2050 (Maximum consensus)	Gawler, Cleve	Avg. annual temperature to increase from 22.1 to 23.31ºC; annual avg. rainfall to increase from 450.2 to 453.4 mm
	RCP8.5, 2050 (Maximum consensus)	Streaky Bay, Kadina	Avg. annual temperature to increase from 22.1 to 24.1ºC; annual avg. rainfall to decline from 450.2 to 430.4 mm
	RCP4.5, 2090 (Maximum consensus)	Streaky Bay, Kadina	Avg. annual temperature to increase from 22.1 to 24.1ºC; annual avg. rainfall to decline from 450.2 to 429 mm
	RCP8.5, 2090 (Maximum consensus)	Cobar, Walgett	Avg. annual temperature to increase from 22.1 to 26.3 ºC; annual avg. rainfall to decline from 450.2 to 395.3 mm
Mt Gambier	RCP4.5, 2050 (Maximum consensus)	Millicent, Penola	Avg. annual temperature to increase from 19.0 to 20.2ºC; annual avg. rainfall to increase from 748.3 to 753.5 mm
	RCP8.5, 2050 (Maximum consensus)	Penola, Wangaratta	Avg. annual temperature to increase from 19.0 to 21.0ºC; annual avg. rainfall to increase from 748.3 to 753.5 mm
	RCP4.5, 2090 (Maximum consensus)	Penola, Wangaratta	Avg. annual temperature to increase from 19.0 to 21.0ºC; annual avg. rainfall to increase from 748.3 to 715.4 mm
	RCP8.5, 2090 (Maximum consensus)	Toowoomba, Perth	Avg. annual temperature to increase from 19.0 to 23.2ºC; annual avg. rainfall to increase from 748.3 to 657.0 mm

[30] CSIRO and Bureau of Meteorology, Climate Change in Australia website, 15 April 2015.

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