Climate change projections for the Adelaide Hills, Fleurieu Peninsula and Kangaroo Island region

resilient hills & coasts

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Climate change projections for the Adelaide Hills, Fleurieu Peninsula and Kangaroo Island

A report prepared for the Resilient Hills and Coasts project

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Contents

Tables

Figures

Acronyms

AMLR NRM region - Adelaide and Mount Lofty Ranges Natural Resources Management region

AR5 - Fifth Assessment Report

BoM – Bureau of Meteorology

CCIA - Climate Change in Australia

CSIRO - Commonwealth Scientific and Industrial Research Organisation

ENSO - El Niño Southern Oscillation

FFDI - Forest Fire Danger Index

GCM - Global Climate Models

IIASA - International Institute for Applied Systems Analysis

IOD - Indian Ocean Dipole

IPCC - Intergovernmental Panel on Climate Change

IVA - Integrated Vulnerability Assessment

NRM - Natural Resource Management

PCTL - percentile

RCP - Representative Concentration Pathways

RH&C - Resilient Hills and Coasts

SACR - SA Climate Ready

SRES - Special Report on Emissions Scenarios

Executive summary

- While there is natural variability in the climate of the Adelaide Hills, Fleurieu Peninsula and Kangaroo Island region, climate change will create a different future climate with warmer and drier conditions and higher sea levels.

- Climate change planning uses climate projection data to assist with undertaking risk and vulnerability assessments and to assist with selecting adaptation options. Projections data has been summarised for the Adelaide Hills, Fleurieu Peninsula and Kangaroo Island using the results of the recent SA Climate Ready (SACR) and Climate Change in Australia projects (CCIA)[1].

- Under an intermediate emissions pathway (RCP4.5) by 2070 for the Adelaide Hills and Fleurieu Peninsula:
    - rainfall is projected to decline by about 6% (SACR, refer Table 2, p12);
    - rainfall intensity could increase by 11% (CCIA/Westra et al, refer p13);
    - maximum temperatures are projected to increase by 1.5ºC (SACR, refer Table 3, p14);
    - minimum temperatures could increase by 1.2ºC (SACR, refer Table 4, p16); and
    - extreme heat in Victor Harbor could increase by 30% to 11 days per year over 35ºC (CCIA, refer Table 5, p18).

- The increase in fire weather for the Adelaide Hills and Fleurieu Peninsula based on projections for Adelaide is an increase from 1.7 severe fire danger days per year under current conditions to 2.6 per year by 2090 under an intermediate emissions pathway (CCIA, refer Table 6, p19).

- Under an intermediate emissions pathway by 2070 for Kangaroo Island:
    - rainfall is projected to decline by about 7.9%(SACR, refer Table 7, p21);
    - rainfall intensity could increase by 8% (CCIA/Westra et al, refer p20);
    - maximum temperatures are projected to increase by 1.2ºC (SACR, refer Table 8, p23); and
    - minimum temperatures could increase by 1.0ºC (SACR, refer Table 9, p25).

- Separate projections for extreme heat and fire weather are not currently available for Kangaroo Island.

- For Ocean and Gulf waters, projections suggest:
    - a rise in sea levels of 33cm by 2070 under an intermediate emissions pathway (CSIRO/BOM, refer Table 10, p26);
    - a rise in sea surface temperatures of 1.2ºC by 2090 under an intermediate emissions pathway (Hope et al, refer p26); and
    - a decline of 0.15 pH units by 2090 under an intermediate emissions pathway (Hope et al, refer p26).

[1] Where available, SACR and CCIA projections are both provided in the body of the report, though where overlaps in projections for the same variable occur, SACR projections have been discussed in text as this provides the best representation of local climate drivers for South Australia. Any significant differences between SACR and CCIA projections are discussed in the relevant climate variable sections. Median figures are presented in the Executive Summary using a baseline period 1986 to 2005, unless otherwise stated.

1 Introduction

1.1 Resilient Hills and Coasts overview

Resilient Hills and Coasts (RH&C) is a climate change adaptation planning project covering the Adelaide Hills, Fleurieu and Kangaroo Island Regional Development Australia (AHFKI RDA) region (Figure 1). The RH&C name is also used to refer to the region covered.

Project partners are:

- Adelaide Hills Council;
- Alexandrina Council;
- City of Victor Harbor;
- District Council of Mount Barker;
- District Council of Yankalilla;
- Kangaroo Island Council;
- Department of Environment, Water & Natural Resources;
- Natural Resources Adelaide and Mount Lofty Ranges;
- Natural Resources Kangaroo Island;
- Regional Development Australia Adelaide Hills, Fleurieu and Kangaroo Island; and
- the Southern and Hills Local Government Association.

As a collective, project partners, with input from community, business, government, industry and academia, undertook the initial phase of the RH&C project in 2014, completing:

- a *Knowledge Audit* describing the regional profile;
- community workshops summarised in a report that describes stakeholder *issues and values*; and
- an *Integrated Vulnerability Assessment* for Kangaroo Island.

The second stage will build on the work completed in 2014 and consider social, economic, environmental, and cultural constructs to present a holistic set of adaptation actions and recommendations. In particular, it will focus on regional priorities that would benefit from multi-organisation cohesion and cooperation, and provide a strong evidence-base for localised planning and action.

During the second stage, Resilient Hills & Coasts, with stakeholder input, will produce and share:

- up-to-date climate change projections for the region;
- a vulnerability assessment describing the key sectors and/ or impact areas; and
- a regional Climate Change Adaptation Plan.

1.2 Study region

The region is home to a population of approximately 120,000 people and covers a land area of 8,752km^2 (Resilient Hills and Coasts 2014). It is characterised by a highly variable topography and geology, from coastal dunes and rocky escarpments to inland fertile hills and pasturelands. The RH&C region supports a range of natural assets, including terrestrial, coastal, aquatic and marine communities, as well as geological phenomena and supports high flora and fauna diversity (including significant species and communities).

The RH&C 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 (Bureau of Meteorology 2015):

- 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; and

- El Niño Southern Oscillation (ENSO), the oscillation between El Niño and La Niña conditions which affects rainfall and temperature in eastern Australia.

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, there are longer term changes in rainfall, temperature and other variables occurring as a result of climate change.

1.3 Purpose of this report

This report provides up-to-date and scientifically-grounded climate change projections for the region. Having an in-depth and holistic understanding of the region's changing climate is a fundamental input to forecasting and analysing vulnerabilities and opportunities. The data presented in this report will inform the RH&C project, and more broadly its partners and stakeholders in adaptation planning.

The next stage of the Resilient Hills and Coasts 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 temperature;
- extreme heat;
- quantity and seasonality of rainfall;
- intensity of extreme rainfall events; and
- frequency and intensity 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 describes the drivers of climate change, sources of variation in climate projections and what climate the region may experience in the future.

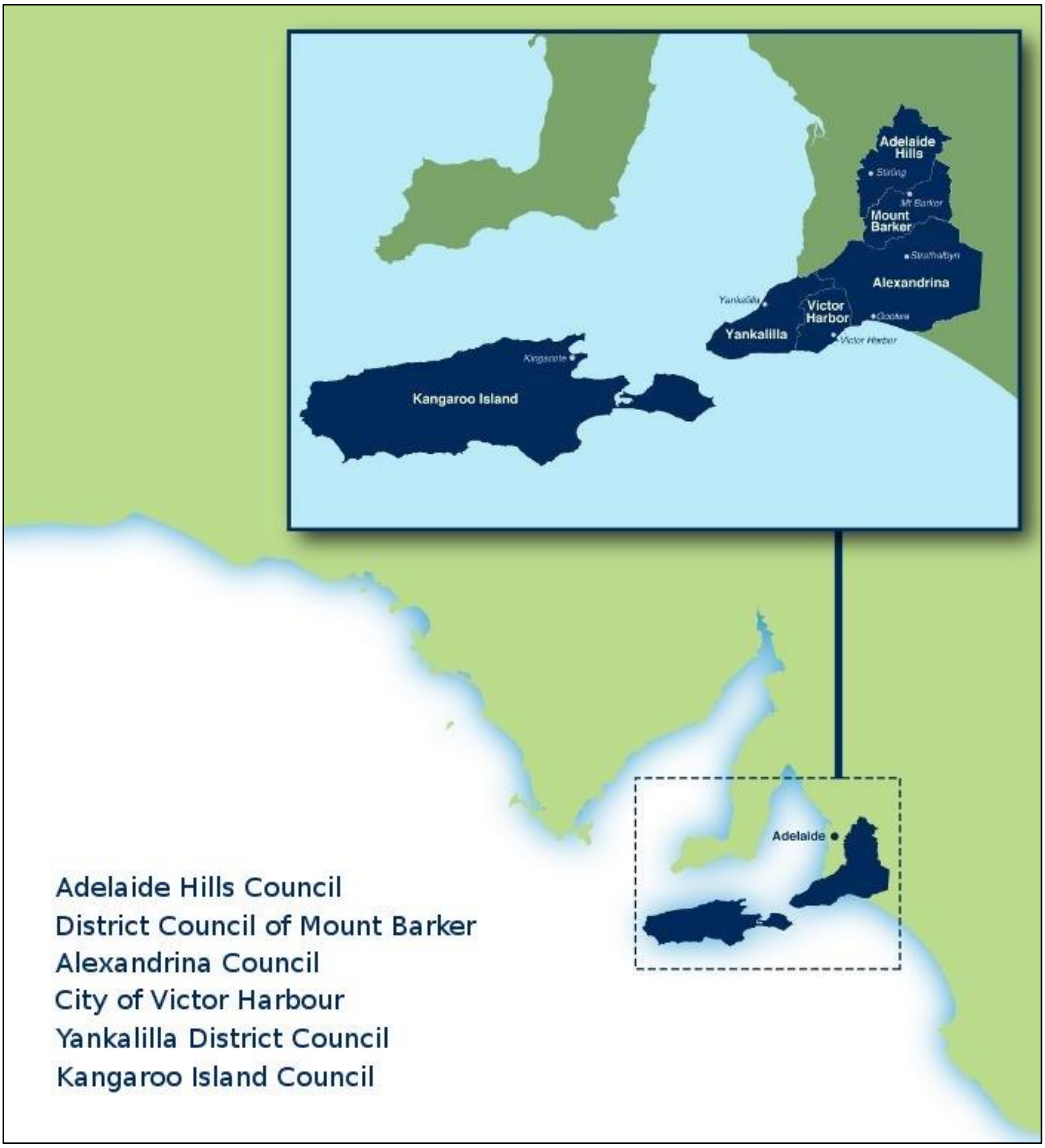

Figure 1. Location of Local Government Areas that comprise the Adelaide Hills, Fleurieu and Kangaroo Island RDA region. Source: RDA Adelaide Hills, Fleurieu and Kangaroo Island.

2 Climate change projections overview

2.1 What is climate change?

Climate refers to the average weather conditions over long periods of time (IPCC 2013a). The World Meteorological Organization defines the climate as the average weather over a 30 year period. Climate change refers to altered climate trends (e.g. increasing temperatures, decreasing rainfall) as averaged over decades or longer. It differs from climate variability which refers to short-term weather fluctuations (1-10 years) (e.g. drought and non-drought cycles) which may occur despite the underlying climate trend. For example, the climate trend of increasing temperature can be occurring even if extreme cold weather periods occur in certain years.

Climate change is a consequence of the release of greenhouse gases like carbon dioxide, methane and nitrous oxide into the Earth's atmosphere (CSIRO and Bureau of Meteorology 2015). 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. These changes include: increasing air temperatures, changes to rainfall patterns, rising sea levels, and increasing sea surface temperatures.

2.2 Climate change modelling

The most authoritative source of information on climate change is provided by the Intergovernmental Panel on Climate Change (IPCC). Every 5-6 years the IPCC produces an Assessment Report which presents the most up-to-date scientific knowledge regarding climate change. The most recent of these reports is the Fifth Assessment Report (AR5), released in 2013. The Assessment Report is a compilation of expert working groups reports which focus on different elements of climate change knowledge: the physical science basis (working group I); impacts, adaptation and vulnerability (working group II); and mitigation (working group III). Climate change modelling results contained in the physical science basis report are used globally to underpin climate change action, including adaptation planning.

Some of the main conclusions presented in the AR5's physical sciences basis report are provided in Box 1.

Box 1. What is the evidence that the Earth's climate is changing? (IPCC 2013b)

The Intergovernmental Panel on Climate Change (IPCC) is the world's leading international body for the assessment of climate change. The IPCC is a scientific body under the auspices of the United Nations. Working Group I of the IPCC made the following conclusions that are relevant to adaptation planning across the world:

- 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.

Further information on the IPCC Assessment Report 5 can be found at: https://www.ipcc.ch/report/ar5/

It is not possible to "predict" or "forecast" what the future climate might be. Instead, climate models use emissions and land-use scenarios to develop a range of "projections" that can be used to explore what future climate conditions may occur. These projections contain inherent variability, which are important to understand when determining how best to use climate data in adaptation planning.

Two of the main sources of variability in climate projections derive from the choice of global climate model/s (GCMs) and representative concentration pathway (RCP), as described below (see also CSIRO and Bureau of Meteorology 2015).

Global Climate Models are numerical models that explore how 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.

Over 40 GCMs have been developed for different regions, variables, and spatial resolutions. When combined, the models can produce global average climate projections. However, when conducting climate modelling at a given location (i.e. not a global focus), the subset of models which best represent the location, resolution and variables of interest are selected in order to minimise variation in the model outputs.

Given the variability that exists across the projections outputs of climate modelling, communication of the outputs often use the median or 50th percentile model output (sometimes described as the “best estimate”), or the 10th and 90th percentile outputs.

Representative Concentration Pathways refer to four main scenarios presented in IPCC AR5 which consider time series of alternative emissions together with concentrations of the full suite of greenhouse gases, aerosols and chemically active gases, as well as varying land-use/land cover to produce alternative future climate conditions (Figure 2) (IPCC 2013a). RCPs replace the previously used Special Report on Emissions Scenarios (SRES). The end of century climate change projections are relatively similar among certain counterpart RCPs and SRESs (e.g. the high emissions scenarios), however, the rate of change over the century varies. Accordingly, projections from modelling conducted for certain future timeframes using SRESs may vary from those conducted using RCPs.

The four main RCPs (Figure 2) outlined in AR5 as the basis for the climate projections (IIASA 2015) are:

- RCP2.5 “Peak and decline scenario” – an emissions pathway leading to very low greenhouse gas concentration levels; a so-called "peak" scenario (radiative forcing peaks at approximately 3 W m–2 before 2100 and then declines);

- RCP4.5 “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 stabilises at approximately 4.5 W m–2 after 2100);

- RCP6.0 “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 m–2 after 2100); and

- RCP8.5 “High emissions scenario” – An emissions pathway characterized by increasing greenhouse gas emissions over time leading to high greenhouse gas concentration levels.

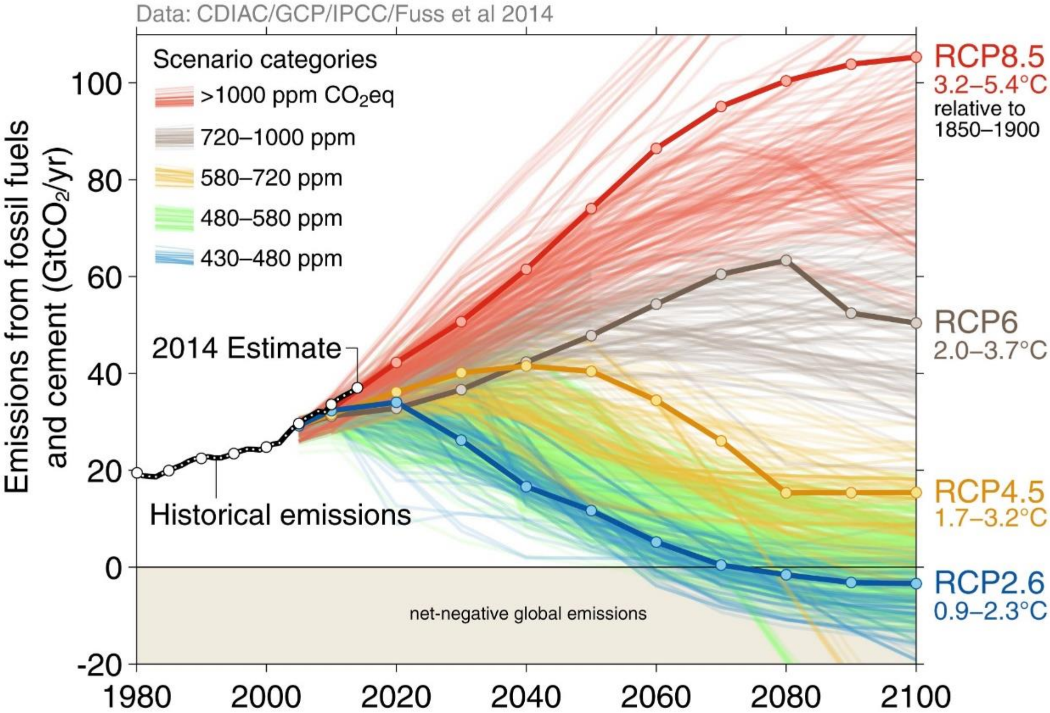

Figure 2. Example of difference in projected global air temperatures over time under alternative RCPs. Bold lines represent the median projection across GCMs, with paler lines indicating the range of variability. Current emissions are tracking along RCP8.5 (Global Carbon Project 2014).

2.3 Projections data available for South Australia

There are two major climate change projection projects relevant to South Australia: SA Climate Ready (SACR) and Climate Change in Australia (CCIA). Both projects use RCPs and GCMs presented in the IPCC's AR5.

2.3.1 SA Climate Ready

The Goyder Institute's "Agreed downscaled climate projections for South Australia" project, called *SA Climate Ready*, was released in February 2015. The project provides regional scale projected climate trends for the State for four future timeframes (2030, 2050, 2070 and 2090), under two RCPs (RCP4.5 and RCP8.5), and for five climate variables:

- areal evapotranspiration;
- rainfall;
- solar radiation;
- temperature; and
- vapour pressure deficit.

SACR climate modelling was refined to the "best" six GCMs based on their ability to reproduce the effects of local climate drivers such as the Indian Ocean Dipole and the El Niño Southern Oscillation.

SACR provides detailed downscaled weather station data for Natural Resource Management (NRM) regions in the State. Three of these NRM regions fall entirely or partially within the RH&C region: Adelaide Mt Lofty Ranges, Kangaroo Island, and the South Australian Murray-Darling Basin.

Further information and regional scale summaries generated from SACR can be found at: www.goyderinstitute.org or https://data.environment.sa.gov.au for access to the detailed datasets.

2.3.2 Climate Change in Australia

Comparatively, the national-focused Climate Change in Australia (CSIRO and Bureau of Meteorology 2015) project used up to 40 GCMs, with the number of models varying depending on the climate variable and RCP of interest, at the resolution of the particular host GCM (~67km to ~333km). 'Application-ready' future climate data is provided to intermediate users (after undergoing on-line training) for eight GCMs.

The CSIRO and Bureau of Meteorology project "Climate Change in Australia: Projections for Australia's NRM regions", referred to as *Climate Change in Australia*, was released in February 2015. The project provides projected climate trends for cluster regions in Australia. The spatial resolution, future timeframe/s, variables, GCMs, and RCPs modelled varies among the clusters. Information for the following climate variables is available:

- fire weather days;
- mean and extreme sea-level rise;
- ocean acidification;
- point potential evapotranspiration;
- rainfall;
- relative humidity;
- sea surface temperature;
- sea surface salinity;
- solar radiation;
- temperature;
- wet areal evapotranspiration; and
- wind speed.

The vast majority of the RH&C region forms part of the Southern and South Western Flatlands East sub-cluster, which covers the Eyre Peninsula, Northern and Yorke, Adelaide and Mount Lofty Ranges, and Kangaroo Island NRM regions. Alexandrina Council also forms part of the Murray Basin cluster, which extends east into Victoria and New South Wales.

Further information on the modelling for each cluster (e.g. GCMs selected) is provided in the Technical Report produced for the project (CSIRO and Bureau of Meteorology 2015). Additional information on the project and access to projection data can be found at www.climatechangeinaustralia.gov.au.

3 How will climate change affect the region?

The projections summarised here are taken from the SACR and CCIA projects. These projects present a range of climate variable projections, RCPs, and future timeframes. However, given differences in available data and for simplicity of communication, projections are based on the following components:

- Nine climate variables (Table 1). Median values are generally referred to in text, though the median and minimum-maximum range of projections are provided in each of the climate variable tables (Sections 3.1-3.3);
- Two RCPs: RCP4.5 and RCP8.5, referred to hereafter as the intermediate emissions pathway and high emissions pathway, respectively; and
- Four future timeframes (2030, 2050, 2070, 2090). Projections for each timeframe are shown in the summary tables but generally only 2050 and 2070 are discussed in text (Sections 3.1- 3.3) as many of the decisions made by stakeholders in the region have 30-50 year lifetimes.

Where available, SACR and CCIA projections are both provided in the summary tables, though where overlaps in projections for the same variable occur, SACR projections have been discussed in text as this project provides the best representation of local climate drivers for South Australia (Table 1). Any significant differences between SACR and CCIA projections are discussed in the relevant climate variable sections.

Non-oceanic variable projections are presented separately for the Adelaide Hills and Fleurieu Peninsula (Section 3.1) and Kangaroo Island (Section 3.2) in order to maintain consistency in reporting given that SACR distinguishes between these regions. Oceanic variable projections are provided for the region as a whole (Section 3.3).

The projections presented here are considered indicative for the region as a whole. However, further consideration of the most appropriate RCPs and GCMs should be given for specific applications, such as impact assessments.

Table 1. Climate variables discussed herein and their availability (tick) or not (x) from the SACR and CCIA projects.

Climate Variable	SACR	CCIA
Rainfall	✓	✓
Rainfall intensity	x	✓
Maximum temperature	✓	✓
Minimum temperature	✓	✓
Extreme heat	x	✓
Fire weather	x	✓
Sea level rise	x	✓
Sea surface temperatures	x	✓
Ocean pH	x	✓

3.1 Climate projections for the Adelaide Hills and Fleurieu Peninsula

3.1.1 Rainfall

By 2050, the annual median rainfall is projected to decline by 6.8% and 7.4% compared with the baseline[2] under the intermediate and high emissions pathways, respectively (Table 2)[3]. By 2070, projected rainfall decline under the intermediate emissions pathway is 6%, compared to 11% under the high emissions pathway.

Under 2070 projections, for example, Mt Barker's current annual average rainfall of 733mm would decline to 689mm under the intermediate emissions pathway and 652mm under the high emissions pathway. Under the same timeframe and pathways, Port Elliot's current 485mm annual average rainfall would decline to 456mm and 432mm.

Seasonal differences in average rainfall are also projected for the region. By 2050, median spring average rainfalls are projected to decline by 11.9% under the intermediate emissions pathway compared to 4.3% and 4.4% in autumn and winter, respectively. Under the high emissions pathway, the spring decline is 21% compared to 3.5% and 4.9% in autumn and winter.

By 2070, the projected decline in median spring rainfall under an intermediate emissions pathway is 16.4%, compared with 3.2-9.6% for other seasons. For the high emissions pathway, the spring decline is 20.6% compared to 7.5-11.6% for other seasons.

The differences between the SACR and CCIA rainfall projections are substantial for some combinations of emissions pathway and timeframe. In general, SACR projects greater declines in rainfall than CCIA. This is most notable for seasonal projections, with SACR projecting notably greater reductions in rainfall for summer, autumn and spring by 2070 under the high emissions pathway.

[2] The baseline is the period 1986 to 2005.
[3] Figures from SACR projections have been included in the text to provide the best representation of local climate drivers for South Australia. However, both the CCIA and SACR projections are provided in Table 2.

Table 2. Adelaide Hills and Fleurieu Peninsula projected median rainfall changes (%) for 2030, 2050, 2070 and 2090. Projections shown are annual and seasonal changes, compared to the baseline, under intermediate (RCP4.5) and high (RCP8.5) emissions pathways.

RCP	SOURCE	2030	2050	2070	2090
ANNUAL					
RCP4.5	**SACR**	-4.7 (-8.9 to -1.0)	-6.8 (-8.8 to -3.5)	-5.7 (-12.9 to -4.7)	-7.7 (-10.7 to -5.0)
	CCIA	-3.7 (-12.9 to 4.5)	-4.2 (-16.8 to 2.4)	-6.3 (-18.0 to 5.4)	-6.7 (-18.3 to 2.6)
RCP8.5	**SACR**	-4.8 (-7.9 to -3.4)	-7.4 (-14.0 to -4.0)	-11.0 (-21.0 to -8.7)	-15.6 (-25.3 to -11.2)
	CCIA	-1.9 (-12.7 to 4.7)	-5.9 (-17.8 to 4.4)	-8.2 (-28.8 to 3.1)	-9.3 (-36.9 to 5.8)
SUMMER					
RCP4.5	**SACR**	-1.6 (-20.7 to 7.7)	-3.0 (-10.4 to 4.6)	-9.6 (-13.8 to 14.3)	-0.8 (-10.9 to 5.5)
	CCIA	0 (-24 to 30.2)	-2 (-18.7 to 16)	-1.3 (-25 to 21.1)	-2.7 (-19.6 to 13.3)
RCP8.5	**SACR**	2.9 (-5.1 to 10.4)	-9.6 (-17.6 to 7.8)	-7.5 (-19.2 to 1.7)	-17.4 (-26.1 to 2.8)
	CCIA	2.1 (-13.8 to 18.6)	-5.8 (-22.8 to 16.6)	0.8 (-28.3 to 21.8)	-3.3 (-26 to 22.3)
AUTUMN					
RCP4.5	**SACR**	-2.2 (-10.4 to 2.7)	-4.4 (-10.5 to 6.0)	-3.2 (-16.3 to 0.9)	-9.3 (-11.7 to 1.4)
	CCIA	-1.2 (-22 to 17.7)	-1.4 (-20 to 23)	-2.5 (-23.5 to 23.6)	-1.8 (-26.4 to 16.5)
RCP8.5	**SACR**	-4.2 (-10.9 to 2.3)	-3.5 (-13.1 to 4.9)	-11.6 (-19.2 to -4.9)	-11.8 (-25.8 to -5.0)
	CCIA	-2.7 (-22.2 to 23.3)	0.3 (-22.7 to 18.1)	-3.9 (-28.8 to 17.3)	1.7 (-33.3 to 33.1)
WINTER					
RCP4.5	**SACR**	0.5 (-7.0 to 4.1)	-4.3 (-9.6 to -0.9)	-6.0 (-9.1 to 1.0)	-5.2 (-9.2 to 1.7)
	CCIA	-5.6 (-16 to 6.4)	-9.4 (-18.9 to 3.4)	-8.2 (-21.3 to 1)	-9.4 (-24 to 2.2)
RCP8.5	**SACR**	-4.4 (-9.2 to -1.6)	-4.9 (-9.4 to -0.6)	-7.6 (-15.5 to -4.6)	-11.9 (-18.5 to -4.9)
	CCIA	-5.3 (-15.5 to 4.8)	-9.2 (-19.3 to 4.3)	-14.9 (-30.4 to -4)	-19.1 (-42.8 to -2.6)
SPRING					
RCP4.5	**SACR**	-12.2 (-18.8 to -9.3)	-11.9 (-20.4 to -8.5)	-16.4 (-26.0 to -8.6)	-15.3 (-25.1 to -12.6)
	CCIA	-5.4 (-20 to 9.8)	-6.4 (-23.1 to 4.9)	-8.9 (-30.9 to 9.4)	-13.6 (-26.3 to 2.9)
RCP8.5	**SACR**	-10.8 (-17.1 to -4.2)	-21.0 (-29.3 to -8.6)	-20.6 (-39.7 to -15.4)	-27.4 (-44.9 to -23.3)
	CCIA	-6.7 (-23 to 10.3)	-7.6 (-34.9 to 14.2)	-12.9 (-41.9 to 9.6)	-18.9 (-49.9 to 8.5)

3.1.2 Rainfall intensity

According to the CCIA project, there is high confidence that the intensity of heavy rainfall events (maximum 1-day rainfall) will increase in the RH&C region, despite projected decreases in mean rainfall. The CCIA does not provide quantitative modelling for rainfall intensity. However, for the purposes of obtaining regional projections, other recent analyses outside of SACR and CCIA has been drawn upon. Westra *et al* (2012) report that for each degree of global warming, extreme daily rainfall may increase by 7%. Applying this multiplier to the projected changes in the Adelaide Hills and Fleurieu Peninsula region, rainfall intensity could increase by 9% and 11% by 2050 under an intermediate and high emissions pathway, respectively, and at least 11% and 16% by 2070.

3.1.3 Maximum temperature

Since national records began in 1910 until 2013, surface air temperatures in the region have warmed by approximately 0.7°C (Hope *et al.* 2015) and are projected to continue to rise under both SACR and CCIA projections.

Compared to baseline temperatures, SACR projects that under an intermediate emissions pathway, annual median maximum temperatures will increase by 1.3ºC and 1.5 ºC by 2050 and 2070, respectively (Table 2). Comparatively, under a high emissions pathway, temperature increases are projected to be 1.6 ºC and 2.3ºC by 2050 and 2070, respectively (Table 3).

To give a regional example, this means that the annual median maximum temperatures at Mt Barker by 2070 could increase from the current 20.3ºC to 21.8ºC or 22.6ºC under an intermediate or high emissions pathway, respectively. Under the same future timeframe and emissions pathways, Parawa annual median maximum temperatures could increase from 17.8ºC to 19.3ºC or 20.1ºC.

Maximum temperatures vary across seasons, particularly for spring. For example, by 2050 under an intermediate emissions pathway, the increase in spring median maximum temperatures is 1.6ºC compared to 1.2ºC for all other seasons; and 2.0ºC compared to 1.5-1.6ºC for all other seasons under a high emissions pathway.

A similar trend continues in 2070, where summer, autumn, and winter median maximum temperatures are projected to increase by 1.3-1.5ºC under an intermediate emissions pathway compared with 1.9ºC in spring. Under a high emissions pathway summer, autumn, and winter increase by 2.1-2.3ºC, and spring by 2.9ºC.

There is little difference in the SACR and CCIA annual projections across RCPs and timeframes, with most projections varying only by 0.1ºC. However, there are more notable differences in projections between seasons, although this is not consistently greater for one project's projections over another.

Table 3. Adelaide Hills and Fleurieu Peninsula projected median maximum temperature changes (ºC) for 2030, 2050, 2070, and 2090. Projections shown are annual and seasonal changes, compared to the baseline (1986 – 2005), under intermediate (RCP4.5) and high (RCP8.5) emissions pathways.

RCP	SOURCE	2030	2050	2070	2090
ANNUAL					
RCP4.5	**SACR**	0.9 (0.7 to 1.1)	1.3 (1.1 to 1.5)	1.5 (1.3 to 1.8)	1.8 (1.5 to 2.2)
	CCIA	0.7 (0.5 to 1.0)	1.2 (0.8 to 1.5)	1.5 (1.1 to 2.0)	1.7 (1.1 to 2.2)
RCP8.5	**SACR**	1.0 (0.9 to 1.4)	1.6 (1.5 to 2.3)	2.3 (2.2 to 3.3)	3.2 (2.8 to 4.3)
	CCIA	0.8 (0.6 to 1.2)	1.5 (1.2 to 2.0)	2.4 (1.9 to 3.1)	3.3 (2.6 to 4.1)
SUMMER					
RCP4.5	**SACR**	0.9 (0.6 to 1.2)	1.2 (1.0 to 1.7)	1.5 (1.2 to 2.0)	1.7 (1.3 to 2.2)
	CCIA	0.7 (0.4 to 1.3)	1.2 (0.9 to 1.8)	1.6 (0.9 to 2.2)	1.7 (1.0 to 2.4)
RCP8.5	**SACR**	0.9 (0.6 to 1.5)	1.5 (1.3 to 2.3)	2.1 (2.0 to 3.3)	2.8 (2.6 to 4.3)
	CCIA	0.9 (0.6 to 1.3)	1.5 (1.1 to 2.2)	2.3 (1.8 to 3.4)	3.3 (2.4 to 4.4)
AUTUMN					
RCP4.5	**SACR**	0.8 (0.8 to 0.9)	1.2 (1.0 to 1.3)	1.5 (1.3 to 1.8)	1.8 (1.5 to 2.2)
	CCIA	0.7 (0.3 to 1.1)	1.1 (0.7 to 1.5)	1.4 (1.0 to 1.9)	1.5 (1.0 to 2.1)
RCP8.5	**SACR**	1.0 (0.8 to 1.3)	1.6 (1.3 to 2.2)	2.3 (2.1 to 3.2)	3.1 (2.8 to 4.3)
	CCIA	0.7 (0.4 to 1.3)	1.4 (1.0 to 2.1)	2.4 (1.7 to 3.0)	3.1 (2.3 to 3.9)
WINTER					
RCP4.5	**SACR**	0.8 (0.5 to 0.9)	1.2 (0.9 to 1.3)	1.3 (1.1 to 1.6)	1.5 (1.3 to 1.8)
	CCIA	0.7 (0.4 to 1.0)	1.1 (0.8 to 1.4)	1.4 (1.0 to 1.8)	1.5 (1.1 to 2.1)
RCP8.5	**SACR**	0.9 (0.7 to 1.2)	1.5 (1.3 to 2.0)	2.2 (1.9 to 2.9)	3.0 (2.6 to 3.9)
	CCIA	0.8 (0.6 to 1.2)	1.4 (1.1 to 1.9)	2.3 (1.8 to 3.0)	3.2 (2.6 to 4.1)
SPRING					
RCP4.5	**SACR**	1.2 (1.0 to 1.3)	1.6 (1.4 to 1.7)	1.9 (1.6 to 2.1)	2.1 (1.8 to 2.5)
	CCIA	0.9 (0.5 to 1.1)	1.3 (0.8 to 1.8)	1.7 (1.1 to 2.2)	1.9 (1.2 to 2.4)
RCP8.5	**SACR**	1.2 (1.0 to 1.7)	2.0 (1.8 to 2.7)	2.9 (2.5 to 3.7)	3.9 (3.2 to 4.9)
	CCIA	0.9 (0.6 to 1.3)	1.7 (1.2 to 2.1)	2.8 (1.9 to 3.2)	3.9 (2.7 to 4.6)

3.1.4 Minimum temperature

Annual median minimum temperatures show a similar trend to maximums, suggesting an increase by 2050 of 1.0ºC and 1.3 ºC under the intermediate and high emissions pathways, respectively (Table 4). By 2070, the SACR projected increase in minimum temperatures under an intermediate emissions pathway is 1.2ºC compared with 2.0ºC under a high emissions pathway.

The difference in projected median minimum temperatures across seasons is generally minimal. By 2050, the SACR projected increases under the intermediate emissions pathway are between 0.8-1.1ºC across seasons, and for the high emissions pathway, 1.2-1.5ºC. By 2070, the range of change increases slightly under the intermediate emissions pathway to 1.0-1.2ºC. It is only under the high emissions pathway for 2070 that the seasonal difference is more pronounced, with summer and winter increases of 1.8-1.9ºC compared with 2.2-2.3ºC for autumn and spring.

As for maximum temperature, there is little difference between the SACR and CCIA projected changes in annual median minimum temperature across RCPs and timeframes. This is also the case for the majority of seasonal projections.

Table 4. Adelaide Hills and Fleurieu Peninsula projected median minimum temperature changes (ºC) for 2030, 2050, 2070, and 2090. Projections shown are annual and seasonal changes, compared to the baseline, under intermediate (RCP4.5) and high (RCP8.5) emissions pathways.

RCP	SOURCE	2030	2050	2070	2090
ANNUAL					
RCP4.5	**SACR**	0.7 (0.5 to 0.8)	1.0 (0.7 to 1.2)	1.2 (0.9 to 1.6)	1.3 (1.0 to 1.9)
	CCIA	0.6 (0.5 to 0.8)	1.0 (0.7 to 1.3)	1.3 (0.9 to 1.6)	1.4 (1.0 to 1.9)
RCP8.5	**SACR**	0.8 (0.6 to 1.1)	1.3 (1.2 to 1.8)	2.0 (1.8 to 2.6)	2.8 (2.3 to 3.5)
	CCIA	0.7 (0.5 to 1.1)	1.3 (1.0 to 1.7)	2.1 (1.7 to 2.8)	2.9 (2.3 to 3.7)
SUMMER					
RCP4.5	**SACR**	0.7 (0.4 to 1.0)	0.9 (0.7 to 1.4)	1.1 (0.9 to 1.9)	1.2 (0.9 to 2.2)
	CCIA	0.7 (0.3 to 1.1)	1.1 (0.7 to 1.5)	1.4 (0.8 to 1.9)	1.4 (0.9 to 2.1)
RCP8.5	**SACR**	0.7 (0.5 to 1.3)	1.3 (1.0 to 2.1)	1.9 (1.7 to 3.0)	2.7 (2.2 to 4.0)
	CCIA	0.8 (0.5 to 1.3)	1.4 (0.9 to 2.1)	2.2 (1.6 to 3.2)	3.1 (2.2 to 4.2)
AUTUMN					
RCP4.5	**SACR**	0.8 (0.5 to 0.9)	1.1 (0.8 to 1.3)	1.2 (1.0 to 1.7)	1.4 (1.1 to 2.1)
	CCIA	0.6 (0.4 to 0.9)	1.0 (0.6 to 1.3)	1.3 (0.9 to 1.7)	1.4 (1.0 to 1.9)
RCP8.5	**SACR**	1.0 (0.7 to 1.2)	1.5 (1.2 to 2.1)	2.3 (1.7 to 3.1)	3.1 (2.5 to 4.2)
	CCIA	0.7 (0.3 to 1.1)	1.4 (1.0 to 1.8)	2.1 (1.6 to 2.8)	3.0 (2.4 to 3.8)
WINTER					
RCP4.5	**SACR**	0.6 (0.4 to 0.7)	0.8 (0.6 to 0.9)	1.0 (0.7 to 1.2)	1.3 (0.9 to 1.5)
	CCIA	0.6 (0.3 to 0.8)	0.9 (0.6 to 1.2)	1.1 (0.8 to 1.5)	1.3 (0.8 to 1.7)
RCP8.5	**SACR**	0.7 (0.5 to 0.9)	1.2 (1.0 to 1.4)	1.8 (1.5 to 2.1)	2.5 (2.2 to 2.7)
	CCIA	0.6 (0.5 to 0.9)	1.2 (0.9 to 1.6)	1.9 (1.5 to 2.5)	2.6 (2.3 to 3.3)
SPRING					
RCP4.5	**SACR**	0.7 (0.5 to 0.8)	1.0 (0.8 to 1.2)	1.2 (1.0 to 1.5)	1.5 (1.2 to 1.7)
	CCIA	0.6 (0.4 to 0.9)	1.0 (0.6 to 1.5)	1.3 (0.8 to 1.7)	1.5 (1.0 to 1.9)
RCP8.5	**SACR**	0.9 (0.7 to 1.0)	1.5 (1.2 to 1.7)	2.2 (1.8 to 2.4)	2.9 (2.4 to 3.2)
	CCIA	0.8 (0.4 to 1.0)	1.3 (0.9 to 1.8)	2.1 (1.7 to 2.7)	3.0 (2.4 to 3.7)

3.1.5 Heat extremes

The whole of the Adelaide Hills and Fleurieu Peninsula region is likely to experience an increase in extreme heat (i.e. number of days over 35ºC or 40ºC) in the future4. However, specific projections of changes in extreme heat using CCIA results are available only for Adelaide and Victor Harbor.

In Adelaide, by 2050 the number of days over 35ºC is projected to increase from 17 per year to 23 or 27 per year under intermediate or high emissions pathways, respectively (Table 5). By 2070, under the same emissions pathways, the number of days over 35 ºC is projected to increase to 25.5 or 31 per year (Table 5). A greater increase occurs for the number of days over 40ºC, with at least a doubling by 2050 under intermediate and high emissions, and an increase from 2 days per year to 5.5 or 8.5 by 2070.

In Victor Harbor, by 2050 the number of days over 35ºC will increase from 7 to 10 or 10.5 under the intermediate or high emissions pathways, and by 2070 will increase to 11 or 14 (Table 5). Under baseline conditions (1986 – 2005), Victor Harbor had not recorded any days over 40ºC. However, by 2050, it is projected to experience 1 or 1.5 days per year above 40ºC under the intermediate or high emissions pathways, and 1.5 or 2 days by 2070.

[4] Extreme heat measures differ from heatwave conditions, with extreme heat being based on total number of days above a thermal threshold, whereas heatwave conditions have more specific definitions, such as “three or more consecutive days with the average of the daily maximum and minimum exceeding 32ºC”.

Table 5. Adelaide and Victor Harbor projected changes in the number of extreme heat days over 35ºC and 40ºC by 2050 and 2070 under intermediate (RCP4.5) and high (RCP8.5) emissions pathways. Values are based on CCIA modelling and are shown for the median number of days under baseline (1986 -2005) and future timeframes, the equivalent percent change (%Δ), and the 10th and 90th percentiles (Pctl).

		Median No. of Days (Baseline)	Median No. of Days (Future)	%Δ	10th Pctl	90th Pctl
ADELAIDE: days > 35ºC						
2050	**RCP4.5**	17	23	35	22	26.6
	RCP8.5	17	27	59	24	30.9
2070	**RCP4.5**	17	25.5	50	24.7	28.6
	RCP8.5	17	31	82	27.7	36.8
ADELAIDE: days > 40ºC						
2050	**RCP4.5**	2	4	100	4	6
	RCP8.5	2	5.5	175	5	7.6
2070	**RCP4.5**	2	5.5	175	5	7.3
	RCP8.5	2	8.5	325	6.7	10.9
VICTOR HARBOR: days > 35ºC						
2050	**RCP4.5**	7	10	43	9	11.3
	RCP8.5	7	10.5	50	10	12.9
2070	**RCP4.5**	7	11	57	10	12.3
	RCP8.5	7	14	100	12	16.2
VICTOR HARBOR: days > 40ºC						
2050	**RCP4.5**	0	1	100	1	1.3
	RCP8.5	0	1.5	150	1	2.3
2070	**RCP4.5**	0	1.5	150	1	2
	RCP8.5	0	2	200	2	2.6

3.1.6 Fire weather

Fire weather projections were estimated in the CCIA project using the McArthur Forest Fire Danger Index (FFDI), which is a widely used measure to forecast the influence of weather on fire behaviour (Hope et al. 2015).

Fire weather is considered 'severe' when FFDI exceeds 50 and 'extreme' when FFDI exceeds 75. The CCIA project generated FFDI projections for four weather stations in South Australia, of which Adelaide is the most relevant to the RH&C region. The other locations in the State are Ceduna, Woomera, and Mt Gambier. FFDI was calculated at Adelaide by Hope *et al*. (2015) for only two future timeframes (2030 and 2090).

The FFDI projections indicate increased fire weather in the future for Adelaide. General fire weather danger is projected to increase by 2030 by 6% or 13% under intermediate or high emissions pathways, and by 12% or 29% by 2090 (Table 6).

The number of days per year with a 'severe' fire danger rating is projected to increase by 2030 from 1.7 under baseline conditions to 2.6 or 2.1 under the intermediate and high emissions pathways, respectively. By 2090, this will increase to 2.6 and 4 days per year (Table 6) (Hope *et al.* 2015).

Table 6. Summary of CCIA's Forest Fire Danger Index (FFDI) calculations for the Adelaide weather station. The baseline period 1981-1995 is used here to calculate change to 2030 or 2090 under intermediate or high emissions pathways (RCP4.5 or RCP8.5, respectively). For both the number of severe fire days per year and the FFDI, absolute projected values as well as projected percent change (%Δ) from baseline are shown.

		Severe Fire Danger Days (per year)	%Δ	Forest Fire Danger Index (FFDI)	%Δ
1995	**Baseline**	1.7	0	2942	0
2030	**RCP4.5**	2.6 (1.9 to 3.5)	90	3336 (3033 to 3885)	13
	RCP8.5	2.1 (1.9 to 2.3)	73	3129 (2985 to 3334)	6
2090	**RCP4.5**	2.6 (2.2 to 2.9)	90	3298 (3126 to 3395)	12
	RCP8.5	4 (2.3 to 5.4)	138	3795 (3085 to 4464)	29

3.2 Climate projections for Kangaroo Island

3.2.1 Rainfall

By 2050, annual median rainfall is projected to decline by 7.5% or 8.9% under intermediate or high emissions pathways, respectively (Table 7)[5]. By 2070, rainfall is projected to decline by 7.9% under an intermediate emissions pathway, compared with 12.5% under a high emissions pathway.

For Kingscote, this would result in a decline in rainfall from the current annual average of 489mm to 450mm or 428mm under an intermediate or high emissions pathway, respectively.

Seasonal differences are apparent by 2050, with spring projected to experience a 13.9% decline in median rainfall under an intermediate emissions pathway, compared to 5.2% and 4.7% decline in autumn and winter, respectively. Under the high emissions pathway the spring decline is 23.8% compared to 5.1% and 8.3% during winter and autumn.

By 2070, the spring decline in median rainfall under the intermediate emissions pathway is projected to be 17.3%, compared to 6.0-9.9% for summer, autumn, and winter. For the high emissions pathway, the decline in spring rainfall is 23.7% compared to 10.1-17.3% for the other seasons.

The difference between the SACR and CCIA rainfall projections is substantial for some combinations of emissions pathway and timeframes. In general, the SACR data projects greater declines in median rainfall than the CCIA dataset. This is most notable for seasonal projections, with SACR projecting greater reductions in 2070 median rainfalls for summer, autumn, and spring under a high emissions pathway.

3.2.2 Rainfall intensity

The CCIA project states that there is high confidence that the intensity of heavy rainfall events (maximum 1-day rainfall) will increase in the RH&C region (Hope et al. 2015). This holds despite projected decreases in mean rainfall.

The CCIA does not provide quantitative modelling for rainfall intensity. However, for the purposes of obtaining regional projections, other recent analyses outside of SACR and CCIA has drawn upon. Westra *et al* (2012) report that for each degree of global warming, extreme daily rainfall may increase by 7%. Applying this multiplier to the projected changes on Kangaroo Island, rainfall intensity could increase by 2050 by nearly 8% and 9%, respectively, under an intermediate ad high emissions pathway/ By 2070, this could increase to 8% and 13%.

[5] Figures from SACR projections have been included in the text to provide the best representation of local climate drivers for South Australia. However, both the CCIA and SACR projections are provided in Table 7.

Table 7. Kangaroo Island projected median rainfall changes (%) for 2030, 2050, 2070, and 2090. Projections shown are annual and seasonal changes, compared to the baseline (1986 – 2005), under intermediate (RCP4.5) and high (RCP8.5) emissions pathways.

RCP	Source	2030	2050	2070	2090
ANNUAL					
RCP4.5	**SACR**	-3.6 (-8.3 to -2.3)	-7.5 (-10.2 to -4.5)	-7.9 (-13.2 to -6.2)	-8 (-11.3 to -5.4)
	CCIA	-3.7 (-12.9 to 4.5)	-4.2 (-16.8 to 2.4)	-6.3 (-18.0 to 5.4)	-6.7 (-18.3 to 2.6)
RCP8.5	**SACR**	-5.9 (-8.8 to -3.1)	-8.9 (-13.9 to -3.8)	-12.5 (-22.2 to -9.7)	-16.9 (-26.4 to -13.3)
	CCIA	-1.9 (-12.7 to 4.7)	-5.9 (-17.8 to 4.4)	-8.2 (-28.8 to 3.1)	-9.3 (-36.9 to 5.8)
SUMMER					
RCP4.5	**SACR**	-5.3 (-23.2 to 1.8)	-8.3 (-18.1 to 9.8)	-9.9 (-20 to 6.4)	-6.9 (-22.7 to 9.8)
	CCIA	0 (-24 to 30.2)	-2 (-18.7 to 16)	-1.3 (-25 to 21.1)	-2.7 (-19.6 to 13.3)
RCP8.5	**SACR**	-3.7 (-15 to 13.3)	-12.3 (-27.4 to 13.1)	-17.3 (-30.5 to -1.8)	-27.1 (-33.9 to 0.4)
	CCIA	2.1 (-13.8 to 18.6)	-5.8 (-22.8 to 16.6)	0.8 (-28.3 to 21.8)	-3.3 (-26 to 22.3)
AUTUMN					
RCP4.5	**SACR**	-1.5 (-14.5 to 6.9)	-5.2 (-13 to 3.9)	-7.5 (-18.9 to 0.6)	-8.2 (-15 to 1.2)
	CCIA	-1.2 (-22 to 17.7)	-1.4 (-20 to 23)	-2.5 (-23.5 to 23.6)	-1.8 (-26.4 to 16.5)
RCP8.5	**SACR**	-6.3 (-12.1 to 3.8)	-8.3 (-14.6 to 4)	-13.7 (-19.2 to 0.2)	-11.8 (-29.4 to -3.9)
	CCIA	-2.7 (-22.2 to 23.3)	0.3 (-22.7 to 18.1)	-3.9 (-28.8 to 17.3)	1.7 (-33.3 to 33.1)
WINTER					
RCP4.5	**SACR**	0.3 (-5.6 to 4.1)	-4.7 (-10.6 to -1.2)	-6 (-9.3 to 0.4)	-5 (-8.3 to 1.8)
	CCIA	-5.6 (-16 to 6.4)	-9.4 (-18.9 to 3.4)	-8.2 (-21.3 to 1)	-9.4 (-24 to 2.2)
RCP8.5	**SACR**	-4.4 (-8.2 to 0.6)	-5.1 (-7.5 to -0.9)	-10.1 (-15.9 to -5.5)	-14.3 (-20 to -5.5)
	CCIA	-5.3 (-15.5 to 4.8)	-9.2 (-19.3 to 4.3)	-14.9 (-30.4 to -4)	-19.1 (-42.8 to -2.6)
SPRING					
RCP4.5	**SACR**	-12.6 (-20.6 to -10.4)	-13.9 (-23.7 to -7.6)	-17.3 (-28.3 to -11.6)	-17.8 (-26.3 to -14.4)
	CCIA	-5.4 (-20 to 9.8)	-6.4 (-23.1 to 4.9)	-8.9 (-30.9 to 9.4)	-13.6 (-26.3 to 2.9)
RCP8.5	**SACR**	-13.5 (-20.7 to -3.2)	-23.8 (-31.9 to -7.6)	-23.7 (-43.2 to -16.7)	-29.9 (-48.7 to -25.9)
	CCIA	-6.7 (-23 to 10.3)	-7.6 (-34.9 to 14.2)	-12.9 (-41.9 to 9.6)	-18.9 (-49.9 to 8.5)

3.2.3 Maximum temperature

Since national records began in 1910 (Hope *et al.* 2015) until 2013, surface air temperatures in the region have warmed by approximately 0.7°C (according to CCIA projections) and are projected to continue to rise under both SACR and CCIA projections.

Compared to baseline[6] temperatures, SACR projects that under an intermediate emissions pathways, annual median maximum temperatures will increase by 1.1ºC and 1.2ºC by 2050 and 2070, respectively (Table 8). Comparatively, under a high emissions pathway, temperatures are projected to increase by 1.3ºC and 1.9 ºC by 2050 and 2070, respectively (Table 8).

An increase in annual median maximum temperatures of this magnitude would see the average maximum temperature at Kingscote increase from the current 19.6ºC to 20.8ºC or 21.5ºC under an intermediate or high emissions pathway, respectively.

Seasonal differences by 2050 are minimal, ranging from 0.9-1.2 ºC under the intermediate emissions pathway and 1.2-1.5 ºC for the high emissions pathway. The difference between seasons for median maximum temperatures by 2070 under an intermediate emissions pathway is limited, with winter temperatures projected to increase by 1.1ºC and spring only slighter higher at 1.4ºC. Under a high emissions pathway summer, autumn and winter are projected to increase by 1.8-1.9 ºC and spring by 2.3ºC.

There is little difference in the SACR and CCIA projections across RCPs early in the coming century. However, by the end of the century the CCIA projected annual median maximum temperatures are notably higher than those generated for the SACR project. This pronounced difference is also evident across seasons, especially for RCP8.5.

[6] Baseline is the period 1986 to 2005.

Table 8. Kangaroo Island projected median maximum temperature changes (ºC) for 2030, 2050, 2070, and 2090. Projections shown are annual and seasonal changes, compared to the baseline (1986 – 2005), under intermediate (RCP4.5) and high (RCP8.5) emissions pathways.

RCP	Source	2030	2050	2070	2090
ANNUAL					
RCP4.5	**SACR**	0.7 (0.6 to 0.8)	1.1 (0.8 to 1.2)	1.2 (1 to 1.5)	1.4 (1.1 to 1.9)
	CCIA	0.7 (0.5 to 1.0)	1.2 (0.8 to 1.5)	1.5 (1.1 to 2.0)	1.7 (1.1 to 2.2)
RCP8.5	**SACR**	0.8 (0.6 to 1.1)	1.3 (1.1 to 1.8)	1.9 (1.7 to 2.6)	2.6 (2.3 to 3.6)
	CCIA	0.8 (0.6 to 1.2)	1.5 (1.2 to 2.0)	2.4 (1.9 to 3.1)	3.3 (2.6 to 4.1)
SUMMER					
RCP4.5	**SACR**	0.6 (0.4 to 1)	1 (0.6 to 1.4)	1.3 (0.7 to 1.6)	1.3 (0.8 to 1.9)
	CCIA	0.7 (0.4 to 1.3)	1.2 (0.9 to 1.8)	1.6 (0.9 to 2.2)	1.7 (1.0 to 2.4)
RCP8.5	**SACR**	0.7 (0.4 to 1.1)	1.2 (0.9 to 1.9)	1.8 (1.4 to 2.6)	2.5 (1.9 to 3.5)
	CCIA	0.9 (0.6 to 1.3)	1.5 (1.1 to 2.2)	2.3 (1.8 to 3.4)	3.3 (2.4 to 4.4)
AUTUMN					
RCP4.5	**SACR**	0.7 (0.6 to 0.7)	1 (0.8 to 1.1)	1.2 (1 to 1.5)	1.5 (1.1 to 1.8)
	CCIA	0.7 (0.3 to 1.1)	1.1 (0.7 to 1.5)	1.4 (1.0 to 1.9)	1.5 (1.0 to 2.1)
RCP8.5	**SACR**	0.8 (0.7 to 1)	1.2 (1.1 to 1.8)	1.9 (1.6 to 2.6)	2.7 (2.2 to 3.6)
	CCIA	0.7 (0.4 to 1.3)	1.4 (1.0 to 2.1)	2.4 (1.7 to 3.0)	3.1 (2.3 to 3.9)
WINTER					
RCP4.5	**SACR**	0.7 (0.4 to 0.7)	0.9 (0.7 to 1.1)	1.1 (0.9 to 1.4)	1.3 (1.1 to 1.7)
	CCIA	0.7 (0.4 to 1.0)	1.1 (0.8 to 1.4)	1.4 (1.0 to 1.8)	1.5 (1.1 to 2.1)
RCP8.5	**SACR**	0.7 (0.6 to 1)	1.3 (1 to 1.6)	1.8 (1.6 to 2.4)	2.5 (2.2 to 3.3)
	CCIA	0.8 (0.6 to 1.2)	1.4 (1.1 to 1.9)	2.3 (1.8 to 3.0)	3.2 (2.6 to 4.1)
SPRING					
RCP4.5	**SACR**	0.8 (0.8 to 1.0)	1.2 (1.1 to 1.4)	1.4 (1.2 to 1.7)	1.7 (1.4 to 2)
	CCIA	0.9 (0.5 to 1.1)	1.3 (0.8 to 1.8)	1.7 (1.1 to 2.2)	1.9 (1.2 to 2.4)
RCP8.5	**SACR**	0.9 (0.8 to 1.2)	1.5 (1.4 to 2.1)	2.3 (2 to 2.9)	3 (2.6 to 3.9)
	CCIA	0.9 (0.6 to 1.3)	1.7 (1.2 to 2.1)	2.8 (1.9 to 3.2)	3.9 (2.7 to 4.6)

3.2.4 Minimum temperature

Annual median minimum temperatures show a similar trend to maximums, suggesting an increase by 2050 of 0.8ºC and 1.1ºC under the intermediate and high emissions pathways, respectively (Table 9). By 2070, the SACR projected increase in minimum temperatures under an intermediate emissions pathway is 1.0ºC compared with 1.6ºC under a high emissions pathway.

The difference in projected median minimum temperatures across seasons by 2050 is minimal for the intermediate emissions pathway (0.7-0.9ºC). In contrast, the difference between seasons is greater for the high emissions pathway with the spring increase of 1.5ºC greater than for other seasons (1.0-1.2 ºC).

By 2070, projected median minimum temperatures across seasons are 0.9-1.1ºC under an intermediate emissions pathway. In contrast, the difference between seasons is greater for the high emissions pathway with the spring increase of 2.2 ºC greater than for other seasons (1.5-1.8 ºC).

As for maximum temperatures, there is little difference in the SACR and CCIA projected changes in annual median minimum temperatures across RCPs early in the coming century. However, differences become more notable by the end of the century. This is also the case for the majority of seasonal projections.

Table 9. Annual and seasonal median minimum temperature rise (ºC) for Kangaroo Island above the baseline period (1986 – 2005) for 2030 to 2090 for the intermediate and high concentration pathways.

RCP	Source	2030	2050	2070	2090
ANNUAL					
RCP4.5	**SACR**	0.6 (0.4 to 0.7)	0.8 (0.6 to 1.1)	1 (0.7 to 1.4)	1.2 (0.9 to 1.7)
	CCIA	0.6 (0.5 to 0.8)	1.0 (0.7 to 1.3)	1.3 (0.9 to 1.6)	1.4 (1.0 to 1.9)
RCP8.5	**SACR**	0.7 (0.5 to 0.9)	1.1 (0.9 to 1.6)	1.6 (1.5 to 2.3)	2.2 (2 to 3.1)
	CCIA	0.7 (0.5 to 1.1)	1.3 (1.0 to 1.7)	2.1 (1.7 to 2.8)	2.9 (2.3 to 3.7)
SUMMER					
RCP4.5	**SACR**	0.6 (0.3 to 0.8)	0.9 (0.5 to 1.2)	1 (0.7 to 1.5)	1.2 (0.8 to 1.8)
	CCIA	0.7 (0.3 to 1.1)	1.1 (0.7 to 1.5)	1.4 (0.8 to 1.9)	1.4 (0.9 to 2.1)
RCP8.5	**SACR**	0.6 (0.4 to 1)	1.1 (0.8 to 1.7)	1.6 (1.3 to 2.5)	2.2 (1.7 to 3.3)
	CCIA	0.8 (0.5 to 1.3)	1.4 (0.9 to 2.1)	2.2 (1.6 to 3.2)	3.1 (2.2 to 4.2)
AUTUMN					
RCP4.5	**SACR**	0.6 (0.4 to 0.7)	0.9 (0.7 to 1.1)	1.1 (0.8 to 1.5)	1.3 (0.9 to 1.8)
	CCIA	0.6 (0.4 to 0.9)	1.0 (0.6 to 1.3)	1.3 (0.9 to 1.7)	1.4 (1.0 to 1.9)
RCP8.5	**SACR**	0.7 (0.6 to 1)	1.2 (0.9 to 1.7)	1.8 (1.5 to 2.6)	2.5 (2 to 3.5)
	CCIA	0.7 (0.3 to 1.1)	1.4 (1.0 to 1.8)	2.1 (1.6 to 2.8)	3.0 (2.4 to 3.8)
WINTER					
RCP4.5	**SACR**	0.5 (0.4 to 0.7)	0.7 (0.6 to 0.9)	0.9 (0.7 to 1.2)	1.1 (0.9 to 1.5)
	CCIA	0.6 (0.3 to 0.8)	0.9 (0.6 to 1.2)	1.1 (0.8 to 1.5)	1.3 (0.8 to 1.7)
RCP8.5	**SACR**	0.6 (0.5 to 0.8)	1 (0.9 to 1.4)	1.5 (1.4 to 2.1)	2.1 (1.9 to 2.7)
	CCIA	0.6 (0.5 to 0.9)	1.2 (0.9 to 1.6)	1.9 (1.5 to 2.5)	2.6 (2.3 to 3.3)
SPRING					
RCP4.5	**SACR**	0.6 (0.4 to 0.6)	0.9 (0.6 to 1)	1.1 (0.8 to 1.3)	1.3 (1 to 1.6)
	CCIA	0.6 (0.4 to 0.9)	1.0 (0.6 to 1.5)	1.3 (0.8 to 1.7)	1.5 (1.0 to 1.9)
RCP8.5	**SACR**	0.9 (0.7 to 1.0)	1.5 (1.2 to 1.7)	2.2 (1.8 to 2.4)	2.9 (2.4 to 3.2)
	CCIA	0.8 (0.6 to 0.8)	1.2 (1 to 1.4)	1.8 (1.4 to 2.2)	2.3 (1.9 to 2.9)

3.2.5 Heat extremes and fire weather

Heat extremes and fire weather projections have not been specifically calculated for Kangaroo Island by the CCIA project. Instead, projections used for the Adelaide Hills and Fleurieu Peninsula region (Sections 3.1.5 and 3.1.6) are also applied to Kangaroo Island.

3.3 Projections for Ocean and Gulf waters

3.3.1 Sea level rise

Rising sea levels will occur as a result of thermal expansion of the oceans as the Earth warms, together with additional water entering the oceans from melting polar ice. Recorded observations of global sea levels between 1880-2009 show a rise of approximately 21 cm, primarily as a result of thermal expansion.

From 1966-2099, sea levels rose around Australia at an average rate of 1.6 mm per year, allowing for sea level changes due to the Southern Oscillation Index (CSIRO and Bureau of Meteorology 2015).

Projections of global median sea level rise for the RH&C region are available for four representative concentration pathways (RCP2.6, RCP4.5, RCP6.0, and RCP8.5), but at only one location, Victor Harbor. The nearest alternate locations are Port Adelaide or Portland.

Projections at Victor Harbor for 2030 indicate a rise of 11cm or 13cm under an intermediate or high emissions pathway (respectively) and 33cm or 40cm by 2070 (Table 10) (CSIRO and Bureau of Meteorology *et al*. 2015).

Table 10. Victor Harbor projected global median sea level rises and their ranges (in parentheses), relative to a 1986-2005 baseline, under all emissions pathways for 2030, 2050, 2070, and 2090.

	Median Sea Level Rise and Range (m)			
	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)

3.3.2 Sea surface temperatures

The world's oceans will continue to warm in the coming century as they absorb heat from the warming atmosphere. By 2030, warming of the ocean could result in a 0.5ºC increase in median sea surface temperatures and a 1.2ºC or 2.2ºC rise by 2090, under an intermediate or high emissions pathway, respectively (Hope *et al.* 2015) and relative to a 1986-2005 baseline.

3.3.3 Ocean acidity

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 7.0) under all future scenarios assessed (relative to a 1986-2005 baseline). Specific projections of changes in pH levels at Victor Harbor indicate a decline of 0.07 or 0.08 units by 2030 under an intermediate or high emissions pathway (respectively), and 0.15 or 0.32 by 2090. This compares with a 0.1pH unit decrease that has already been experienced since the beginning of the industrial era about 250 years ago (Hope *et al.* 2015).

3.4 Climate analogues

The Climate Analogues tool[7] available on the CCIA website allows users to match the projected future climate of a location to other locations currently experiencing similar climate conditions. The matching is based on annual average rainfall and maximum temperature data. This function allows users to better comprehend the implications of future climate change in their location of interest by considering the current conditions in another location.

For example, the tool was applied to the RH&C region (Table 11) using the maximum consensus[8] model outputs for annual median temperature increases of up to 0.5 ºC and annual median rainfall declines of up to 10%. This narrow range of temperature and rainfall enables a more concise identification of analogue locations. Within the RH&C region, analogues were only available for Victor Harbor and Kingscote for the timeframes of 2050 and 2090.

In 2050, Victor Harbor's climate is predicted to be similar to the current climate of Nuriootpa and Port Lincoln (under an intermediate emissions pathway), whereas Kingscote will be more similar to Yorketown's current conditions. By 2090, Victor Harbor's climate will be closer to Adelaide and Keith currently, and Kingscote will be more similar to current climate conditions in Nhill in the Wimmera region of Victoria.

[7] Some potentially important aspects of local climate are not considered with this approach, such as frost days, solar radiation, and soil types. As such, the analogues should not be used directly for adaptation planning.
[8] Maximum consensus is based on the degree of agreement among global climate models.

Table 11. Climate analogue analysis results for Victor Harbor and Kingscote using maximum consensus outputs for average annual temperature increases of 0.5 ºC and annual median rainfall declines of 10% (relative to a 1986-2005 baseline).

		Analogue locations	Annual average temperature increase	Annual average rainfall decline
Victor Harbor				
2050	**RCP4.5**	Nuriootpa, SA; Port Lincoln, SA	From 20.1ºC to 21.4ºC	From 523.6mm to 488mm
	RCP8.5	Adelaide, SA; Keith, SA	From 20.1ºC to 21.8ºC	From 523.6mm to 465mm
2090	**RCP4.5**	Adelaide, SA; Keith, SA	From 20.1ºC to 22.1ºC	From 523.6mm to 463.4mm
	RCP8.5	Port Pirie, SA Griffith, NSW	From 20.1ºC to 24.1ºC	From 523.6mm to 373.3mm
Kingscote				
2050	**RCP4.5**	Yorketown, SA; Bordertown, SA	From 19.8ºC to 21.8ºC	From 455.4mm to 424.4mm
	RCP8.5	Yorketown, SA; Horsham, VIC	From 19.8 ºC to 21.5ºC	From 455.4mm to 404.4mm
2090	**RCP4.5**	Echuca, VIC; Nhill, VIC	From 19.8ºC to 21.8ºC	From 455.4mm to 403mm
	RCP8.5	Quorn, SA; Penong, SA	From 19.8ºC to 23.8ºC	From 455.4mm to 324.7mm

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5 Glossary

Unless stated otherwise, all definitions are from IPCC (2013a).

Aerosol - A suspension of airborne solid or liquid particles, with a typical size between a few nanometres and 10 μm that reside in the atmosphere for at least several hours. Aerosols may influence climate in several ways: directly through scattering and absorbing radiation and indirectly by acting as cloud condensation nuclei or ice nuclei, modifying the optical properties and lifetime of clouds.

Atmosphere - The gaseous envelope surrounding the Earth.

Baseline/reference - The baseline (or reference) is the state against which change is measured.

Climate - Usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years.

Climate change - Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.

Climate change in Australia (CCIA) – a national-focused climate change project released in February 2015 and led by the CSIRO and Bureau of Meteorology (CSIRO and Bureau of Meteorology 2015).

Climate model (spectrum or hierarchy) - A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties.

Climate variability - Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events.

Emission scenario - A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., greenhouse gases, aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships.

Greenhouse gas - Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and by clouds.

Global climate model (GCM) – also called general circulation models are mathematical representations of the climate system which explicitly represent large-scale synoptic features of the atmosphere (CSIRO and Bureau of Meteorology 2015).

Integrated vulnerability assessment (IVA) – a process used to assess the likelihood (or exposure) and consequence (or sensitivity) of climate change impacts on key issues, as well as assessing the adaptive capacity of issues in order to ensure a full understanding of vulnerabilities (Local Government Association of South Australia 2015).

McArthur Forest Fire Danger Index (FFDI) - The McArthur Forest Fire Danger Index (FFDI) is widely used to forecast the influence of weather on fire behavior. FFDI is based on the temperature (˚C), T, wind speed (km h-1), v, relative humidity (%), RH, and a component representing fuel availability called the Drought Factor (Dowdy *et al*. 2009).

Projection - A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized

Radiative forcing - Radiative forcing is the change in the net, downward minus upward, radiative flux (expressed in W m–2) at the tropopause or top of atmosphere due to a change in an external driver of climate change.

Regional climate model (RCM) - A climate model at higher resolution over a limited area. Such models are used in downscaling global climate results over specific regional domains

Representative concentration pathways (RCP) - 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/land cover.

South Australia Climate Ready (SACR) – A Goyder Institute research project to develop an agreed set of downscaled climate change projections for South Australia to support proactive responses to climate change in water resource planning and management at a State and regional scale (Goyder Institute 2015).